THE HEALTH OF WELDERS IN HER MAJESTY'S DOCKYARDS AT DEVONPORT, PORTSMOUTH, ROSYTH AND CHATHAM

Volume 2 of 2

A series of epidemiological research studies seeking evidence that welding has damaged the health of welders in Her Majesty's Dockyards with proposals for improved health precautions and surveillance.

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SECTION A

A RETROSPECTIVE ANALYSIS OF ABSENCE ATTRIBUTED TO SICKNESS BY WELDERS, SHIPWRIGHTS, BOILERMAKERS, ELECTRICAL FITTERS, PAINTERS AND JOINERS EMPLOYED IN HER MAJESTY'S DOCKYARDS - DEVONPORT, PORTSMOUTH AND ROSYTH

Summary

Absence attributed to sickness by welders and men in two control groups during a five year period has been studied in terms of frequency and severity. Differences between welders and controls with respect to age and smoking habits have been considered. Data on this and on manpower turnover, selected employment, medical discharges and deaths during employment are presented.

It is concluded that there is no evidence of an excess of absence among welders which can be attributed to respiratory or other disease caused by welding pollutants but that these pollutants may prompt welders with respiratory disorders to be absent more readily than controls. The other health parameters studied show no evidence of an excess of respiratory ill-health.

1. INTRODUCTION

If, as some believe, welders' health is adversely affected by their work, it could be expected that this would be reflected in their absence from work attributed to sickness. This has not been investigated previously. In this study this absence is compared with that of two groups of other employees in the same Dockyards who are exposed to welding pollutants occasionally, (Control group 1 - boilermakers and shipwrights) and are virtually never so exposed (Control group 2 - electrical fitters, painters and joiners).

However, sickness absence is not synonomous with ill health. It is a behavioural phenomenon more accurately described as absence accepted by the employer as attributable to sickness or injury. Its patterns are affected by many variables other than ill health and thus may not reflect the health of the employees. It is believed that a fair assessment of the health of welders relative to other occupations, and especially in relation to respiratory diseases, can be obtained if these complicating variables are considered in the study.

This report describes the methods and results of a five year retrospective study of sickness absence experienced by welders and the control groups at Devonport, Portsmouth and Rosyth Dockyards in which the effects of several complicating variables have been considered. The report includes a description of the experience of discharges and job relocation on medical grounds and of deaths while in employment.

2. METHODS

2.1 Population

The population studied comprises constructive welders and men in five other craft groups in two control groups. Control group 1 is made up of boilermakers and shipwrights. These men do not weld but may work in areas where welding is taking place or may actually work with welders and are considered to have intermittent exposure to welding pollutants. Control group 2 comprises electrical fitters who work in workshops, painters and joiners. These men are unlikely to have any exposure to welding. All the men worked in one of three of Her Majesty's Dockyards during a recent five year period: Devonport 1.1.71 - 31.12.75, Portsmouth 1.9.72 - 31.8.76, Rosyth 1.1.72 - 31.12.76. The welding processes used are described in volume 1.

The population includes all men who had been employed for at least six consecutive months in the Dockyard concerned as a craftsman welder, boilermaker, electrical fitter ashore, painter and joiner or shipwright. In the case of the shipwrights a 1 in 3 stratified random sample was drawn before detailed data was collected on these individuals. If a man was still employed on the last day of the survey period he is considered to be in the Employed Population. Alternatively the Discharged Population contains all men who were discharged from the craft groups either to leave the Yard or to accept promotion to a supervisory grade or died while still in employment during the survey period. The Combined Population comprises all men.

The 1 in 3 random sample of all shipwrights who qualified for inclusion in either the Employed or Discharged Population was drawn to give a craft group of more similar size to the others thereby spreading the data collection task more evenly over the groups. When selecting this sample from those shipwrights who were qualified for inclusion in the Discharged Population the group discharged each year was sampled rather than the total group.

2.2 Definitions

Certificated sickness absence is absence from work attributed to sickness, supported by a certificate provided by the employee's general practitioner and accepted as such by the employer. A diagnosis is stated on this certificate. Any absence exceeding three days must be supported by a certificate.

Uncertificated sickness absence is absence from work attributed to sickness which does not exceed three days and which is supported only by the employee's statement which is accepted by the employer. Regulations limit the amount of uncertificated sickness absence to ten days in any twelve months.

The age of each subject for comparisons of absence was taken as that at the mid-point of the survey period but for discussion of mortality, medical discharges and job relocation, the actual age at the event is used.

Smoking habit categories

- Smoking : at least one cigarette or equivalent each day.
- Smoker : smoked for at least one year prior to the end of his work period and was still smoking at the end of the work period.
- Ex-smoker : having smoked for at least one year of his life and stopped smoking at least one year prior to the end of his work period.
- Non-smoker: never smoked or started/was smoking before the end of the work period but did not qualify as a "smoker" as defined above.
- Undefined : no information available.

Work period: period a subject was employed within the survey period.

Indices of frequency and severity of absence

Two indices of frequency of absence were calculated; the rate of new spells per thousand man years and the inception rate of spells per 100 persons. New spells per thousand man years takes account of all spells of absence and all men in thé Combined Population and is calculated by dividing the total number of spells of absence by the total number of years worked by the men within the survey period. Annual inception rate per 100 persons was calculated by dividing the sum of the yearly number of subjects having one or more spells in each of the years within the survey period by the number of complete years worked by the men and expressing this as a percentage. A subject and his spells are included in the calculation of inception rate only for the complete years (relative to the starting dates of the survey) he was in the study. The indices of severity were the mean annual duration (days) calculated by dividing the total days of absence by the total man years at risk and the mean length of spells (days), estimated by total absence divided by the total number of spells. Only a man's spells of absence during his Dockyard employment within the study period are considered in these indices of absence.

2.3 Data collection - Employed Population

A nominal list of all men employed in the six craft groups on the last day of the study period in each Naval Base was prepared from the payroll computer file. The date of entry to employment was determined and those men who had been employed for a minimum of six consecutive months before the end of the survey period were included in the population. The random sample of shipwrights was drawn. A nominal list of the Employed Population was then completed and the undernoted information was obtained from a variety of existing records for each man.

a. National Insurance Number for use as a personal data file identifier.

b. Date of birth

c. Marital status (deduced from PAYE Income Tax Code Number and thus restricted to married or single).

d. Work Centre Number (used to send correspondence and as cross check on occupation).

e. Dates of all certificated sickness absence from Dockyard employment during study period. These were obtained independently from Finance Department and Medical Centre records. The number, dates and duration of spells obtained from these two sources were cross-checked and inconsistencies resolved.

f. Certificated cause of absence for all spells of certificated sickness absence was matched to each spell. Respiratory disorders were coded to WHO ICD 1965.

g. Total days of uncertificated sickness absence for each subject in the study period was extracted from Finance Department computer files and manuscript Personal Records independently and cross-checked.

h. Any medical restrictions on type of work and reason for these restrictions (only at Devonport).

After discussions with Trade Unions and Management a questionnaire (Appendix A1) seeking information about smoking habits and the journey to work was agreed and distributed to each man by hand. This questionnaire was accompanied by an explanatory letter and a reply envelope. Further explanation and encouragement to complete and return the questionnaire were given by articles in Naval Base newspapers, by posters and meetings with Shop Stewards. Trade Union representatives were kept informed of the patterns of response in each craft group without identifying individual non-responders and they investigated pockets of non response with considerable success. A further issue of questionnaires was made to non-responders after a two week interval. When a returned questionnaire contained incomplete or ambiguous information a letter seeking further answers or clarification was sent to the man.

2.4 Data collection - Discharged Population

A nominal list of all men in the six craft groups who had been discharged or died while employed during the study period having completed six consecutive months employment was prepared from manuscript records. The sample of shipwrights was drawn. Those who died during employment and those discharged on medical grounds were identified and the cause of death or discharge recorded from mortality records maintained in the Research Unit and Dockyard Medical Centre Records respectively.

The items of personal information recorded for the Employed Population were obtained. The last known address was sought in addition to the Work Centre.

A register of all deaths among males over 16 years in Plymouth or with a home address in Plymouth and of all deaths of men employed in the Dockyard is maintained in the Research Unit. This was searched to identify men who had died since leaving Dockyard employment. The date and certificated cause(s) of death were coded to WHO ICD 1965.

After consultation with Trade Unions a questionnaire seeking information about smoking and the journey to work during the study period was sent to the last known address of all known survivors. Articles about the study were placed in local and Dockyard newspapers and local radio stations were provided with and used news features.

If there was absolutely no response from a man (or his next of kin) within one month and the questionnaire was not returned by the Post Office a re-issue was made.

Many questionnaires were returned by the Post Office because the men were no longer at the address held by MRU. To obtain current addresses Electoral Rolls and telephone directories were searched and informal interviews held with former work mates and Trade Union representatives. Details of men for whom no address could be obtained were sent to the Department of Health and Social Security. This Department identified several men who had died and provided copies of the Certificates of Cause of Death and forwarded questionnaires to men for whom a current address was available. These addresses were not revealed to the research team. On completion of this exercise some men remained untraced. Details of these and other non-responders were sent to the Office of Population Censuses and Surveys to determine if the men were alive or dead and if dead, the cause(s) of death. Only ten men remained untraced. They were all young electrical fitters in the Rosyth Discharged Population who were not at addresses held by MRU and DHSS but are known to be alive.

Some non-responders in the Discharged Population had responded to other MRU studies in 1972-73. The smoking history was taken from these records for those non-responders who left or died in these years. These and Dockyard Medical Centre Records provided smoking habit data for many of those who had died.

2.5 Statistical analyses

In addition to estimating crude rates for each craft group subdivided by age and smoking habit categories direct standardised rates have been calculated.

The direct standardised rates are based on two sets of information:-

1. the specific 'cell' rates for the craft group being studied, and
2. the distribution across the various strata for a 'standard' population which is taken to be the aggregate of the craft groups being studied.

The direct adjusted rate $R_s(i)$ for craft group i is simply

$$R_s(i) = \sum_{j,k,l...} \left[c_{i,j,k,l...} \quad \sum P_{i,j,k,l\,...} \right]$$

where $C_{i,j,k,l}$ is the specific rate for craft group i and subgroups j,k (eg, age, smoking category) l... of the various subdividing factors, and $P_{i,j,k,l...}$ is the corresponding proportion of the 'standard' population (eg number of men or number of man-years) in the sub-categories.

2.6 <u>Security and confidentiality of information</u>

The Medical Research Unit staff were subject to the Official Secrets Act and in addition were required to sign a specific declaration for each Dockyard study. MRU staff conducted all record searches and handling of uncoded data. The questionnaire and all records containing personal or medical information were classified "medical in confidence" and were identified by a number which could be related to an individual only by use of a two stage coding system. These two codes were stored separately in secure containers with access restricted to only the writer and his deputy.

Access to computer files was restricted to two members of MRU staff. These files were protected by special programming techniques which were impossible to by-pass without access to the programme files which were stored in a special security area.

2.7 Quality control

All staff engaged in record searches, coding and tabulating were told at the beginning of the study that quality controls would operate. A record was kept of each task performed by each member of staff so that the source of clerical errors could be identified.

Whenever possible data obtained from one source was cross-checked with the same data obtained by another member of the team from a separate source. In other cases spot sample checks were run frequently. Computer systems included data validation programmes.

3. RESULTS

3.1 Population

Number of men

There are 4052 men in the Combined Population (Devonport 1769, Portsmouth 1358, Rosyth 925), 2710 in the Employed and 1342 in the Discharged Population. The Combined Population comprises 533 welders; 517 boilermakers and 835 shipwrights making up 1352 in Control group 1; and 999 electrical fitters, 403 painters and 765 joiners giving 2167 men in Control group 2 (table A1).

Manpower movements

Welders have the highest average work period during the years surveyed, 4.3 years, with groups 1 and 2 having averages of 3.8 and 3.2 man-years respectively (table A2). Welders had the lowest percentage manpower reduction between the first and last days of the first four years of the survey period, 7.2%; Control group 1, 12.4% and Control group 2, 8.1%. This analysis had to be limited to the first 4 of the 5 year period as men leaving in the last year would have had an opportunity to complete the six month qualifying period while their replacements entering the Yards in the last 6 months would not have that opportunity. This would have resulted in an overstatement of change for a decreasing work force, and an understatement of change for an increasing workforce.

Age

Welders have the highest mean age, 44.8 years, of the three groups, the others being 37.5 years in Control group 1 and 40.1 years in Control group 2 (table A3). Relatively few welders are under 35 years while a relatively high proportion of the other groups are under this age. In both Control groups the age-group proportion decreases with increasing age until the oldest group in which there is a relatively high proportion in Control group 2 (table A3, Figure A1). Within the craft groups which form the

Control groups there is a notably high proportion of electrical fitters <25, 36%, and of joiners in the oldest age group, 41.2% (table A3).

In the Discharged Population the majority of men are in the age groups under 35 and over 54 in all three groups (table A4, figure A2). Among the welders more than half the men are over 45 years, the proportions in two age groups 45-54 and 55 plus being much greater (20.2% and 50.5%) than in corresponding groups in Control group 1 (9.1%, 28.0%) and Control group 2 (7.0%, 37.7%).

Marital status

There is considerable variation between welders and Control groups in the percentage of men who are married (table A5). The low rate of 65.1% in Control group 2 is due largely to the electrical fitters with a rate of 56%. Group differences in the percentage of married men reflect the heterogenous age distributions and therefore have not been considered further in the analysis.

3.2 Tobacco smoking

Availability of information on smoking habit

Data on smoking habit is available for 88.3% of the Combined Population, 94.1% of the Employed and 77.2% of the Discharged (the latter Population includes 105 men who were dead when the questionnaire was issued). Most of this information was obtained by questionnaire but for five men in the Employed Population and 98 in Discharged who failed to respond to the questionnaire data was obtained from contemporary records. Absence statistics for those for whom no information on smoking habit was obtained are shown and these men were included in standardisation calculations.

Within the Combined Population the proportion who can be allocated to a smoking habit category is similar in the welders and controls (welders 90.8%, Control group 1, 89.1%, Control group 2, 87.1%) but varies slightly with age within these groups (table A6, figure A3).

Smoking habits of the Combined Population

Among those for whom smoking habit is known a higher proportion of welders (60.3%) are smokers than those in the Control groups (53.7% and 54.2% respectively) and a lower proportion are non smokers - welders 20.7%, Control group 1, 25.8% and Control group 2, 27.4% (table A8, figure A4). Similar proportions of each group are ex-smokers.

Information on smoking habit is more complete when considered in terms of man years at risk as the proportions for which no information is known are smaller (table A9). The relative proportions of welders and controls in each smoking category are similar to those noted above.

3.3 The journey to work

Information on the length of the journey to work, the mode(s) of transport used and the number of changes involved was provided by 91.8% of the Employed Population but only 70% of the Discharged Population as the latter includes men who were dead by the time the information was sought and as no information was available from other sources on these men, analysis has been restricted to the Employed Population. The relative position of the Dockyards to centres of population is different and thus the journey to work has been studied in each Yard Employed Population separately. The response rates in each were similar; Devonport 92.1%, Portsmouth 92.4% and Rosyth 91.2% with slight intra-Yard variations in the number of men providing satisfactory answers to the various questions (table A10). Within each Yard the proportion of welders, Control group 1 and Control group 2 living at various distances from the Yard was of the same order though there were notable differences between Yards (table A10, figure A5) especially where there is a small number of men in the subgroups, eg welders at Devonport >9 miles.

Very few men used more than one mode of transport. In each Yard the proportion of welders and controls walking or cycling to work and using bus or car were of similar order though there was considerable variation between Yards (table A11, figure A6). At Devonport relatively more welders (32.7%) used the bus than Control group 1 (22.8%) and Control group 2 (24.4%) with compensating reductions in those using car. At Rosyth relatively fewer welders than Control group 1 walked or cycled, 11.1% and 16.6% respectively with reverse relationships in those using the bus but the numbers walking/cycling are very small in both groups.

Indices of frequency and severity of all certificated absence are related to the length of the journey in table A12 and to the mode of transport used in table A13. There is no constant relationship between distance and absence. Those living furthest from work have more new spells than others but that rate does not increase sequentially with increasing distance. Those who travel by bus have rather more new spells which are slightly longer than for men in other categories.

3.4 Restricted employment due to infirmity

The Dockyards operate a selected or restricted employment scheme whereby any employee, who in the opinion of the medical staff is unfit to carry out the full range of work in his occupation, is given work commensurate with his residual abilities. Men in this scheme at Devonport were studied and the results are shown in table A14. Proportionately almost three times the number of welders than men in each control group were in selected employment. The excesses were mainly due to cardiovascular and musculoskeletal which together accounted for 21 of the 32 welders.

3.5 Medical wastage

When a man's health is so incompatible with any employment in his occupation in the Yard he may be given early retirement on medical grounds. Other men may die while employed. Data on these aspects of health have been collected for welders and all men in the Discharged Population (not a 1:3 sample of shipwrights) who were aged 39 years and over at the mid-point of the survey period (table A15). Of those at risk 6.1% welders, 12.4% Control 1 and 9.3% Control 2 died or were medically discharged. Disorders of the respiratory system accounted for 2 of 23 welders (8.6%), 14 of 67 Control 1 (20.9%) and 24 of 101 Control 2 (23.8%). The mean ages of those discharged in each group were similar; welders 57.6 years, Control 1, 54.5 years and Control 2, 59.7 years.

3.6 First and final days of spells

The proportion of the total number of spells for each broad classification of absence and all absence starting and finishing on each day of the week was similar for welders and controls. The frequency distribution for the first day of spells of absence attributed to respiratory disease is shown in table A16 as an example.

3.7 Indices of sickness absence

All absence (certificated and uncertificated)

The rate of new spells per 1000 man years in each group describes a parabola descending steeply from the youngest age group to 25-34 years then more gradually to that over 54 years (figure A7). The age specific rate for welders is lower than that for each control group in all age groups but especially below 35-44 years (table A17, figure A7). Welders have the lowest crude overall rate, 3189, with Control groups 1 and 2 having rates of 4256 and 4030 respectively (table A18, figure A8). Standardisation for age differences reduces the differences between the rates (3631, 4055 and 4012 respectively), standardisation for smoking habit makes little difference, and after standardisation for age and smoking together welders still have the lowest rate of 3561 with Control group 1 at 4049 and Control group 2 4008 (table A18, figure A8).

Comparison of the crude rates related to smoking habit (table A19, figure A9) shows no constant relationship in ranking of the rates between smoking categories but ex-smokers tend to have fewer new spells. Standardisation for age within smoking categories (table A 20, figure A 9) clarifies the ranking a little with ex-smokers in each study group having the lowest rates while non-smokers tend to have slightly higher or similar rates to smokers. Welders rank third (lowest) in each smoking habit category.

The inception rate per 100 persons in each group falls with increasing age to 45-54 years after which that of both control groups rises slightly while that of welders continues to fall (figure A10). In no age group is the rate for welders notably higher than that for either control group (table A 21, figure A10). The overall crude rates are in the ranges 43-50 welders having the lowest rate (table A22, figure A11). Standardisation hardly alters the rates and the dual standardisation for age and smoking together gives rates of 44 for welders, 49 for Control group 1 and 45 for Control group 2 (table A 22, figure A11).

Among the welders and Control group 2 smokers have the highest inception rates before and after standardisation while there is little difference between the smoking habit groups in Control group 1, (tables A 23, A 24 and figure A12). Welders rank 3 (lowest) in non-smokers and smokers and 2 in ex-smokers.

Mean annual duration of absence in all three groups is longest in those under 25 where welders have the longest absence with 33.4 days in the range 33.4 to 22.1, and over 54 years where welders have the shortest duration in the narrower range 28.9 to 22.5 years. Welders aged 25-34 years have the shortest annual absence, 13.2 days (table A 25, figure A 13). The understandardised group mean annual durations are very similar in all groups; welders 21.5, Control group 1, 22.4 and Control group 2, 21.3 (table A 26, figure A 14). Standardisation for the effect of smoking habit makes little difference while that for age and with smoking narrows the range a little to 23.1 to 20.6, welders ranking 2 with 20.8 days (table A 26, figure A 14).

Smokers have longer mean annual duration of absence than non-smokers and ex-smokers both before and after standardisation in all groups except Control group 2 before standardisation when the index for smokers is 23.0 and for ex-smokers 23.2 days (tables A 27, A 28, figure A 15). There is little variation between smokers in the craft groups. Welders who have never smoked or have stopped smoking have shorter absence than non-smokers in the control groups (tables A 27, A 28 and figure A 15).

The mean length of spell increases sharply with age in all study and age groups except in welders where there is a fall between those under 25 and those aged 25-34 years (figure A 16). Welders have the longest spells of those aged under 25, 35-44 and 45-54 years, the differences being greatest among the oldest men (table A 29, figure A 16). Welders have the longest spells overall, 6.8 days compared to 5.3 days for each control group. Standardised rates involving age show little or no difference between the three study groups (table A 30, figure A 17). Smokers tend to have slightly longer spells, even when the effects of age have been considered (tables A 31, A 32 and figure A 18). Welders have the longest spells in all three smoking categories before age standardisation but only in smokers after standardisation. The differences are small, all under 2 days.

Absence attributed to respiratory disease

The data relate only to certificated absence. The rate of new spells per 1000 man years varies with age similarly in all three groups reducing sharply from a relatively high rate in those under 25 years where welders rank 2 with a rate of 608 to age group 25-34 then falling constantly, but less gradually through the remaining age groups (table A 33, figure A 19). Welders have prime ranking in the age group 35-44 years but, as in all age groups over 25 years the range of rates is quite narrow (table A 33). Welders have the lowest overall crude rate of 290; Control groups 1 and 2 have rates of 332 and 319 respectively (table A 34). Differences in age distribution exert a stronger influence than those in smoking habit (table A 34, figure A 20) age standardisation alone resulting in virtually identical rates. Welders rank 3 in dual standardised rates.

Welders who have never smoked have a considerably lower rate than their control counterparts, those who currently smoke have a slight excess relative to both controls especially after age standardisation while those who have stopped smoking have a lower rate than Control group 1 but higher than Control group 2 (tables A 35, A 36 and figure A 21). With or without age standardisation welders who smoke have a higher rate than ex-smokers who have a higher rate than non-smokers.

Inception rate per 100 persons shows similar but slightly less variation with age in all three study groups as the rate of new spells per 1000 man-years (table A 37, figure A 22). There is a sharp fall between the first and second age groups then a gradual fall to age 45-54 years after which there is little change. Welders have similar rates to the controls throughout with slightly higher rates among the older men. The overall crude rates are very similar (table A 38, figure A 23) welders and Control group 2 each with rate of 22 and group 1, 25. Age and age-smoking standardisation narrows the range to 22-24, welders ranking 2 in both cases.

Welders who have never smoked have the lowest rates among the welders and control groups of the same smoking category both before and after standardisation (tables A39, A40 and figure A24). There is very little difference in rates of welders who smoke and their controls even after consideration of age differences and the differences between the ex-smokers are similarly small, the range after standardisation being 20-25, welders 23.

Mean annual duration of absence varies much more with age than the indices of frequency of absence in all 3 groups describing a bi-phasic curve falling from the youngest age group to 25-34 years, rising in 35-44 years, falling again but only slightly in the welders in the 45-54 age group and finally rising to almost the under 25 years duration in those over 54 years. Welders have a middle or low ranking to age group 35-44 years and over 54 years but the longest durations between 35 and 54 years (table A41, figure A25). The overall crude rates lie in the narrow range of 5.3 to 5.0 welders having the prime position (table A42, figure A26). Standardised durations remain in a similarly narrow range, the dual age and smoking standardised index being 5.0 for welders, 5.1 for Control group 1 and 4.9 for Control group 2 (table A42, figure A26).

Non-smoking welders have the shortest mean annual duration both before (3.4 days) and after (3.3 days) age standardisation (tables A43, A44 and figure A27). Welders who smoke have the longest duration of absence before and after standardisation (6.5 days and 6.4 days respectively) than other smokers and indeed all other subgroups. The ex-smokers among the welders have the lowest rate among ex-smokers, 3.5 days, almost as short as welders who have never smoked.

Mean length of spell generally increases with increasing age with the minor exceptions of welders age 25-34 and Control group 1 age 45-54 years where there is a slight fall (table A 56, figure A 28). There is little difference between groups in all but these two groups. Welders have a rather longer mean length in age group 45-54, 21.7 days in contrast to 15.2 Control group 1 and 17.5 in Control group 2. Welders have the longest unstandardised group mean length of spell, 18.2 days, with the control groups close together at 15.4 and 15.8 respectively (table A 46, figure A 29). While standardisation for smoking habit makes no real difference that for age alone and age-smoking standardisation narrows the range to 16.5-15.4 days with welders having mid ranking, 15.7 days in the latter case.

Non-smoking welders who had spells of absence attributed to respiratory disease had spells averaging about 3 days longer than their controls (table A 47, figure A 30) but this was largely a function of age as standardisation for that variable results in very similar lengths of spell (table A 48, figure A 30). Welders who were smokers during the survey period showed a similar pattern relative to the smokers in the control groups, the differences in the crude data (welders 19.7 days, Control 1, 16.5 and Control 2, 17.2 days) being reduced after standardisation. Welders who had stopped smoking had slightly shorter spells than their controls. Welders who smoked at the time of the survey had longest spells of all.

Absence attributed to upper respiratory tract disease

In general, the rate of new spells per 1000 man-years for each group decreases with increasing age (table A 49, figure A 31). With one exception, age 35-44 years, welders have low to middle ranking. Welders have the lowest crude overall rate, 233, with Control group 1 ranking one at 281 and Control group 2 ranking 2 with 273 (table A 50, figure A 32). Standardisation for age differences does not alter welders relative ranking which is maintained through each of the other standardisations albeit with a narrowing range, 271-252 in the dual standardised rate.

Non-smoking welders have the lowest rate of all sub-groups before and after age standardisation (tables A51, A52 and figure A32) while those who smoke have the highest rates among the smokers the range widening after standardisation. Considering the three groups there is no constant relationship between smoking habit and this index of upper respiratory tract disease.

Inception rates follow very similar patterns of variation with age and study groups but the variations are smaller (tables A53-A56, figures A34-A36). In the crude overall rates welders rank 3 with a rate of 18, Control group 1 having a rate of 22 and Control group 2, 20 (table A54, figure A35). Standardisation for smoking habit makes no difference while that for age and age + smoking narrow the range to 21-19, welders having the lowest rate.

Welders who have never smoked have notably lower rates before and after standardisation than their controls (tables A55, A56 and figure A36). There is little difference between the smokers in the three study groups while the rate for ex-smokers in Control group 1 is slightly higher than welders and Control group 2 especially before the indices are adjusted for age.

Mean annual duration of absence generally decreases with increasing age (table A57, figure A37), welders having lowest or middle ranking indices in each age group but 45-54 years in which they have the largest mean annual duration but in all groups the differences are small. This is emphasised by the overall crude indices, welders 3.8 days and both Control groups 3.9 days (table A58, figure A38) and standardisation scarcely alters these indices.

Non-smoking and ex-smoking welders have the lowest mean annual duration of these smoking habit sub-groups before and after standardisation (tables A59, A60 and figure A39). Welders who smoke have the longest mean annual duration even after standardisation. All these differences are relatively small.

Mean length of spells generally increases with increasing age (table A 61 and figure A 40). There is no constant ranking relationship between welders and control groups. Welders aged 45-54 have the longest spells of all, notably longer at 21.5 days than their controls 13.7 days and 17.1 days respectively. Welders overall crude mean length of spell is longest at 16.2 days with the control group having 13.8 and 14.3 respectively (table A 62, figure A 41). Standardisations involving age remove these differences almost entirely.

Non-smoking welders have slightly longer spells (15.6 days) than the controls (12.8 and 13.1 days respectively) but the differences are much reduced by age standardisation (tables A 63, A 64 and figure A 42). Welders who smoke have slightly longer spells and this difference survives standardisation.

The welders who have stopped smoking have the shortest spells after the data has been age standardised.

Absence attributed to lower respiratory tract disease

The rate of new spells of absence per 1000 man-years in welders and Control group 1 falls sharply from the youngest where the rates are 73 and 77 respectively to the 25-34 years group where rates are 42 and 40. Control group 2 has a much lower rate in those under 25 (table A 65, figure A 43). Rates in welders and both control groups remain more or less constant to 45-54 years where welders have a relatively high rate of 56 compared to Control group 1, 42 and Control group 2, 40. All three study groups have higher rates in the oldest age group, welders having the highest rate, 75.

Welders have the highest overall crude rate, 56, compared to 51 in Control group 1 and 47 in Control group 2 (table A 66, figure A 44). Standardisation does not affect the rank order but those standardisations involving age reduces the differences between welders and group 1 while a difference of 11 and 10 remains between welders and Control group 2.

Non-smokers generally have less absence attributed to lower respiratory tract disease than smokers and ex-smokers, age standardisation making little alteration to the rates (tables A67, A68 and figure A45). Ex-smokers in Control group 2 are exceptions to this trend. Welders who have never smoked have lower rates than their controls but those who are smokers or ex-smokers have higher rates than their controls. The difference between welders and Control group 1 is less than between welders and Control group 2.

Inception rate per 100 persons is low in all study groups and sub-groups. It follows the same general variations between study groups with increasing age except that welders take up their prime position one age group earlier at 35-44 years (table A69, figure A46). The range is narrow in each age group and in the overall crude rates where welders rank 1 with a rate of 5 compared to a rate of 4 in each control group (table A70, figure A47). Standardisations does not alter rates nor ranking.

Those who have never smoked tend to have lower inception rates than others in each group but the differences are really quite small (tables A71, A72 and figure A48). Welders who smoke or have smoked have prime ranking among their counterparts. Control group 2 has the lowest rate in each smoking habit category.

Mean annual duration of absence increases with a narrow range with increasing age after a slight drop from that of those under 25 years (table A73, figure A48) welders ranking 1 or 2 in all age groups. The crude overall durations emphasise the similarities between groups; welders 1.5 days, Control group 1 1.3 days and Control group 2, 1.1 days (table A74, figure A50). After age standardisations welders and Control group 1 exchange rankings but the differences remain minimal. Smokers have longer mean annual duration of absence attributed to lower respiratory tract diseases than all others even when age differences have been considered (tables A 75, A 76 and figure A 51). Before age standardisation welders have the longest duration of the smokers but after adjustment for age differences they and Control group 1 have the equal durations. Non-smoking welders have the same or shorter absence than Control group 1. After standardisation, Control group 1 takes prime ranking and welders and Control group 2 have very similar durations. All mean annual durations are less than 2 days.

<u>The mean length of spells</u> is similar for those in the youngest age group of all three study groups (welders 13.4 days, Control group 1, 12.0 days and Control group 2, 12.4 days) (table A 77, figure A 52). There is a general increase with age, welders and Control group 1 having notable peaks in age group 35-44 years (welders 40.2, Control group 1, 34.3 and Control group 2, 21.3 days) followed by a fall to similar durations in all groups then a rise in the oldest age group. Welders have relatively high ranking until that age group where they have the shortest spells.

For the mean length of spells welders show a slight excess over others but this is removed by standardisations involving age (table A 78, figure A 53).

Smokers have longer spells than others in each study group the difference being most marked in the welders where, after age standardisation smokers average spells of 30.0 days, non-smokers 20.5 days and ex-smokers 12.9 days (tables A 79, A 80 and figure A 54). Welders have the longest spells of non-smokers and of smokers but the differences are smaller than between smoking categories.

Absence attributed to diseases other than respiratory

The rate of new spells of absence reduces with increasing age in all three study groups, welders having low to middle ranking rates in all age groups (table A 81, figure A 55). This is reflected in the overall crude rates (welders 439, Control group 1, 608 and Control group 2, 516) and in all standardised rates (table A82, figure A56).

Welders and those in Control group 2 who are smokers have higher rates than their counterparts who have never smoked or have stopped smoking but Control group 1 does not share this pattern (table A83, figure A57). Welders have the lowest rates in each smoking category before standardisation and in non-smokers and smokers after standardisation (table A84, figure A57

Inception rate per 100 persons follows the same relation with age as noted for rate of new spells welders having middle to low ranking in all age groups except 35-44 years and 45-54 years, where they have prime ranking in range 31-34 and 28-29 respectively (table A85, figure A58). Control group 1 has the highest crude rate, 37, with welders and Control group 2 having similar rates of 31 and 32 respectively (table A.86, figure A 59). Standardisation for age and for smoking separately and together scarcely alters these rates. Welders have the lowest rates in each smoking category before and after standardisation (tables A 87, A 88 and figure A 60).

Mean annual duration fluctuates wildly with age in welders due mainly to a long duration in those aged under 25 and a short duration in the next age group (table A89, figure A61). In general, after fluctuations in the youngest men there is fairly constant mean annual duration in both control groups until age 54 when there is a sharp rise. The rise for the welders aged 35 or more is less severe with the averago length for the over 54's less than that of the control groups

The overall crude rates are very similar (welders 13.6, Control group 1, 13.8, Control group 2, 13.0) and virtually unaffected by smoking habit standardisation (table A 90, figure A 62). Age standardisation increases the difference between the highest rate, Control group 1, and the others.

Those who have never smoked have an average shorter annual duration of absence for non-respiratory disease than others (tables A 91, A 92, figure A 63) even when age differences have been considered and, in that sub-group, welders and ex-smokers have least absence. Among the smokers welders have slightly greater absence, 15.0 days, than the control groups (14.3 days and 13.6 days respectively) but lose this prime ranking when age is considered. The ranges are very narrow.

Mean length of spells increases sharply with age in all groups. The few youngest welders are the only exception (table A 93, figure A 64). Welders have prime position in all but one age group in the age range 35-54 has spells approximately five days longer than Control group 2. This ranking is reflected in the crude and standardised rates (table A 94, figure A 65) where welders have prime ranking throughout.

Non-smokers have shorter spells than others in all groups before and after age standardisation (tables A 95, A 96 and figure A 66). Welders have the longest spells in each smoking habit category before standardisation and in the smokers after age standardisation.

4. DISCUSSION

4.1 Methods

Validity of sickness absence patterns as indicators of ill-health

Sickness absence is a behavioural phenomenon affected by many variables and more correctly defined as absence accepted by the employer as attributable to sickness or injury (Taylor, 1976). This does not mean necessarily that it cannot reflect ill-health of groups of workers. In fact it has been shown that there is a close correlation between symptoms of chronic bronchitis recorded at examination and both the number and duration of spells of absence attributed to that disease (Jedrychowski, 1976). The use of sickness absence as an indicator of ill-health is probably more valid when only certificated absence is considered. The workers in this study are permitted to take a total of ten days uncertificated absence each year and it is thought that most abuse of the sickness absence scheme is likely to be restricted to that privilege.

The several variables noted in the literature to affect absenteeism and in particular sickness absence are listed in tables 2A - 2C. Those in table 2A are common to welders and controls. All these subjects are male craftsmen (similar status) working on non-repetitive work in small units and are employed in Her Majesty's Dockyards at Devonport, Portsmouth and Rosyth. These Dockyards have the same basic type of work and a common set of regulations governing promotion, working hours, wage rates, incentive systems, sick pay and pensions. (HM Dockyard Chatham was excluded because a radically different pay scheme operates there). Interviews with Personnel Managers showed that interpretation of central policy was similar in all Yards. All subjects were qualified to receive medical treatment from National Health Service facilities in addition to that available from the Dockyard Occupational Health Service. All welders except one were Caucasion and personal observations showed that very few men of other racial types were employed in the control groups. Information about race was not sought by questionnaire as the topic can excite unjustified but troublesome attention. The surveys were conducted during the same seasons and state of national and local economy in each Yard's area.

TABLE 2A. Variables common to welders and control groups

Status	Work group size	Type of organisation	Sex
Working hours, wage rates and incentive/reward systems.			Sick pay
Pension scheme	Personnel policy	Insurance benefits	Health services
Medical services	Race	Season	State of economy
General practitioner			

TABLE 2B. Variables included in experimental design

Occupation (and working conditions)	Health	Age	Smoking habit
Labour turnover and length of service	Marital status		
Journey to work	Day of week spell started/finished		

TABLE 2C. Variables considered but not included in experimental design

Geographical area.	Supervisory quality and leadership style	
Personality	Job satisfaction	Other employment

The certificate of unfitness to work or of fitness to return to work issued by the employee's general practitioner is the keystone of the sickness absence certification system used routinely in the Dockyards and in this study. The validity of these certificates is frequently criticised by occupational physicians and others (Fortuin, 1955, Hodgkin, 1970, Moffat, 1970, Coe, 1975) who consider that absence certificates are available virtually "on demand" and/or that return certificates are rarely issued without the patient's consent, and that the certificated diagnosis is often based on only a subjective opinion especially in absences of short duration. It is probably true that some general practitioners do issue certificates "on demand". In other cases the doctor cannot confirm nor deny or even determine the extent to which work ability is impaired. Diagnosis may often be largely subjective following examination to exclude critical underlying causes of symptoms. The role of the general practitione could have been an important variable if there was evidence of clustering of welders or controls in particular practices. While this has not been investigated specifically formal studies of the length of the journey to work and informal studies of home addresses during the questionnaire issue has shown no craft or control group clustering and, as general practices draw their patients from the surrounding residences it is considered that the subjects are randomly distributed between the available practices and doctors.

Comparisons of indices of absence have been made on broad classifications of disease types as this is more valid than using statistics derived from certificates as absolute measures of the level of any particular disease process or cause of incapacity in the population (Whitehead, 1972). Validit is further improved when respiratory diseases are considered as these are not commonly chosen by employees as reasons for malingering absence, subjective conditions such as backache being much more popular (Hodgkin, 197

Some of the other potentially confounding variables were considered in the experimental design. These are listed in table 2B. The effect on health of working conditions as represented by occupation is the study variable. Age has a well-recognised effect on absence patterns (Buzzard and Shaw, 1952) and variations are obvious in the crude rates in this study. As the age-frequency distributions of welders and controls are notably different indices of absence have been standardised using the Combined Dockyard Populations as reference. Tobacco smoking is known to initiate or exacerbate certain respiratory diseases and standardisation has been done to remove group differences in the proportions of smokers, ex-smokers and non-smokers again using the Combined Population as reference.

Early in the study it was found that many craftsmen who had just completed their apprenticeship formed a particularly mobile group with a high level of short absence shortly before they left the Yard to take up employment elsewhere. The qualifying period of six consecutive months employment as a craftsman was introduced to minimise the effects of these variables related to labour turnover and length of service.

Studies have shown that men with three or more children have consistently higher sickness absence rates than those with no children or smaller families (Whitehead, 1972). This was thought to be related to occupation with unskilled and semi-skilled workers tending to have larger families and often receiving as much remuneration from sickness benefit as from their wage. All the men in the current study are skilled workers and thus this variable should not have a strong influence. Special family responsibilities such as an invalid wife may also be reflected in absence rates. It was considered that questions about size of family and special responsibilities might be considered intrusive and irrelevant by the subjects and therefore data collection was limited to marital status (married or single) to give an indication of the possible strength of these variables.

Transportation difficulties may increase absence rates. These difficulties may take the form of long distances to travel to work, absence of direct public transport links, long travel time (Stockford, 1944; Knox, 1961., Isambert-Jamati, 1962., Martin, 1971). Not all investigators agree. For example Hill (1967) and Nicholson and Goodge (1976) found no relationship between either travel distance or availability of public transport and absence. However, none of these reports relate to populations similar to those in this study. From personal experience as a Medical Officer in two of these Yards, increased difficulty in getting to work does seem to represent a possible impediment to attendance behaviour for some employees. This was investigated in terms of the length and mode of the journey to determine if differences existed between welders and controls and if absence patterns varied with either.

Among the variables considered in the experimental design was the day of the week spells of absence started and finished. Men cannot work at weekends as the Yards are virtually closed and thus spells starting or finishing on weekends would be artificially long. The start and finish days of spells have thus been studied to detect any differences between welders and control groups.

Finally, some potentially confounding variables were not studied formally (table 2C). While it is generally accepted that there are regional differences in sickness absence rates these have been shown to be related to other regional factors such as the distribution of industry and average earnings per man. As these are common to the three Dockyards and to all those in the study groups it was considered that this need not be considered further.

It was not possible to investigate subjects' personalities, job satisfaction, the effect of group norms, their assessment of supervisors attitude and ability nor if they had any secondary employment "moonlighting". Such questions would have required extensive questionnaires which would have included questions which could be considered impolitic and intrusive. Existing research has produced only weak support for the hypothesis that job dissatisfaction represents a primary cause of absenteeism (Vroom, 1964., Porter and Steers, 1973., Locke, 1976., Nicholson et al, 1976). Factors affecting job satisfaction include job scope, job level, role stress, worker group size, leader style and opportunity for advancement (Steers and Rhodes, 1978) and must be related to the employee's personality and expectations. Several of these items are common to all groups. Role stress is more likely to be found in supervisory grades with role conflict and in blue collar workers with repetitive closely timed jobs (Hedges, 1973) than among the craftsmen in this study where the men are doing "one of" tasks, know their place in the heirarchy and in the job in hand, and make real decisions, albeit in a narrow range of expertise. Pressure for and against attendance can also emerge from colleagues in the form of group norms (Cartwright and Zander, 1968., Shaw, 1976) which may be strongly influenced by supervisors' attitudes to absence but only two studies of several have shown a significant inverse relationship between job satisfaction, supervisory style and absenteeism.

Choice of indices of absence

Several authors have recommended the study of frequency distributions of sickness absence events rather than average rates (Froggat, 1968., Behrend, 1978), because the statistical significance of differences between frequency distributions can be tested simply while this cannot be done for absence rates, the observed distribution can be compared to that which would arise on a specified hypothesis of causation (such as negative binomial for proneness, Poisson for chance) and subjects with repeated absence can be identified for interview in order to rectify the cause.

However using frequency distributions requires that all men who leave or join during the year(s) or are absent for a significant period must be identified and discarded as they will have reduced exposure to risk (Froggat, 1968). This is a serious disadvantage as it must result in a survivor and thus biased population.

It has been shown that comparisons between average rates for reasonably comparable groups in the same industry can be made safely since the generating distributions are likely to be similar (Froggat, 1968).

Thus it was decided to use average rates and to minimise statistical errors, as both those employed throughout the period and those entering or leaving could be included. As the groups and sub-groups are large relatively valid comparisons can be made more safely between the indices. Rates can also be standardised as required while maintaining relative large numbers of men in groups while comparison of frequency distribution, eg for men with different smoking habits would have resulted in small numbers of men in the several separate age and smoking habit distributions.

These errors may be composed of sampling errors (the only sample drawn was of the shipwright), response errors (incorrect information provided by the men, eg on smoking habit), non-response errors (no information from some individuals) and data processing errors.

Unfortunately errors do not balance out and differences between averages or rates may underestimate or overestimate the true differences. If for instance a relatively large number of men were classified as "unknown" smoking habit and should in the main be non-smokers or smokers then information based on the known non-smokers or smokers should be regarded only as approximate estimates of the "true" values. The larger the "unknown" associated with a factor the less reliance should be placed on the "known" sub-groups of the factor. The percentage of unknown in this study is relatively small and similar in welders and controls.

Similarly too much sub-grouping of a factor will lead to a few small size sub-groups providing information which may be dependent on the erratic behaviour of a few individuals. The standardised rates may put heavy emphasis on some small sub-groups with resulting odd patterns. While reduced sub-grouping of a factor can hide possible interesting features in the data but the estimates of averages and rates will then not depend too much on a few erratic subjects.

4.2 Results

Manpower movements

If a specific occupation is recognised by the employee to be adversely affecting his health, it would not be unreasonable to expect him to seek alternative employment, that if the welder in the Yards thought that welding was responsible for causing respiratory symptoms he would leave after a short time. However, welders had, on average, longer service per man in the Yards during the study period than each of the control groups despite the welders being an older group in which one could expect more discharges due to normal retirement. They also had the lowest percentage reduction in man-power. While external factors such as reduced opportunity may be responsible for these observations, eg poor job opportunities elsewhere there is no basis for concluding that working conditions are provoking welders to leave after short periods of employment.

Age

All other things being equal one could expect welders to have longer absence than controls on account of them forming an older group. This may have influenced observations expressed by some Trade Union representatives that welders appear to be less healthy than those in other trades. The relatively high proportion of welders in the older age groups of the Discharged Population is a reflection of the age distribution of the Employed Population rather than an indication that welders have left in relatively greater numbers than controls.

Smoking habits

No information was available on the smoking habit of 11.7% of men in the Combined Population. This represents 5.8% of the total man-years at risk. There is very little difference between the response rates in welders and controls nor in the mean age of responders and non-responders. While this unknown quantity must detract from the safety of firm conclusions on the relationships between occupation, smoking and absence it is hoped that the distribution of these men in the smoking categories is similar to that of the responders. In general, the age-standardised frequency and severity of absence of the "undefined" has been found to lie between non-smokers and smokers, strengthening the view that responders and non-responders are of similar smoking habits.

The higher proportion of smokers and lower proportions of non-smokers among welders could be expected to be associated with an excess of respiratory diseases especially chronic bronchitis, bronchial carcinoma and, as they have been exposed to asbestos, parenchymal fibrosis.

The journey to work

We recognised that it would be very difficult to assess the effects, if any, of the journey to work on absence without very detailed questioning and we wished to avoid this if possible. The questions asked were in effect a pilot to determine if a strong effect was apparent. If this was so a more detailed study would have been undertaken but, as has been shown, there was no correlation between distance, mode of transport and absence. Thus we have not proceeded further. One can appreciate that a man who feels slightly unwell is more likely to stay away from work if he has to make several changes of transport during his journey or even travel by public transport rather than going from door to door by car. Moreover a man with dyspnoea may be able to get to work by bus if his home and the bus stop are on the same level but not if he has to climb a hill to the stop.

From the information available almost no men have to change transport en route; special buses are run on many routes to give a direct service. With so many possible variables affecting the choice of transport it was considered that no reliable additional information would be provided by standardising the sickness absence indices for differences in the journey to work.

Selected employment, medical discharges and deaths in employment

Caution must be exercised in comparison of rates of selected employment and medically related discharges between and within industrial concerns because of the great diversity in the requirements imposed for flexibility of the labour force and in the regulations governing medical discharges. Respiratory diseases encountered in the general working population do not require the termination of employment as often as non-respiratory disorders (Haber, 1971) and more often involves placing limitations on the type or amount of work allowed (Wan and Wright, 1973). The extent to which limitation might result in invaliding depends on the requirement of the job, the elasticity of the organisation in accepting departures from usual job requirements and the capacity of the individual to compensate for and adjust to losses in functional disabilities.

In this study the working situation allows most men to be offered selected employment commensurate with their abilities. It is believed that the main exception is the limited amount of bench work available to welders, shipwrights and boilermakers with musculo-skeletal disorders especially backache. However the statistics on selected employment show that a relatively large number have been accommodated. These facilities are provided in relatively well-ventilated workshops, ideal for those with respiratory disorders, yet despite this very few welders (and controls) appear to require to be relocated for these disorders. In short the selective employment data provide no evidence of an excess of respiratory disease in welders over controls. Data on medical discharges and deaths provide further support to this view.

Sickness absence patterns

The null hypothesis is that having considered relevant confounding variables, there is no excess sickness absence among welders over their controls.

When all absence, certificated and uncertificated, is considered there is certainly no evidence of any excess frequency among the welders. They have the lowest rates of new spells per 1000 man-years and, with the exception of the age-standardised inception rate where they rank 2 with the same rate as Control group 2, they have the lowest inception rate. Their mean annual duration of absence is very similar to their controls especially after age standardisation. They rank 2 in all rates. The slight excess in the mean length of spells, 6.8 days compared to 5.3 days in each control group, is removed when the effects of age on absence patterns are allowed for.

If welding does adversely effect health the respiratory system is the most likely target. Welders could have similar patterns of total absence but an excess of absence attributed to respiratory disease - if absent for this reason they cannot be absent concurrently for other reasons. When our comparisons are restricted to certificated absence attributed to respiratory disease welders have the lowest crude and standardised rate of new spells per 1000 man-years. Inception rates in all three study groups are very similar, welders ranking 2 in both crude and standardised rates. Mean annual durations vary little between groups - all within the range 4.9 to 5.2 days and once again the slight excess in the crude mean length of spells taken by welders, 18.2 days against Control group 1, 15.4 days and Control group 2, 15.8 days, is substantially reduced when the effects of age are considered and is lost when the index is standardised for both age and smoking. Thus there is no evidence of an excess of absence attributed to respiratory disease as a whole which can be associated with occupation as a welder.

The data related to upper respiratory tract disease show welders to have the lowest rate of new spells and inception rates before and after standardisation. Mean annual duration is virtually the same in all three groups but welders do have slightly longer mean length of spell (16.2 days compared to 13.8 and 14.3 in the control groups) before age standardisation.

When we consider lower respiratory tract disease the number of episodes is small in all groups. Welders have the highest crude rate of new spells exceeding that of Control group 1 by 5 days and Control group 2 by 9 days. This difference between welders and Control group 1 is largely removed by age standardisation while that between welders and Control group 2 remains. Inception rates are low 5%, 4% and 4% respectively before and after standardisation. Thus there is evidence of a slight excess in the number of spells of absence among welders but not of the proportion of men having these spells.

With the relatively small number of spells mean annual duration of absence is expectedly short in all groups and little can be concluded from differences of these orders. The mean length of spells is longer, welders ranking 2 when age is considered, Control group 1 having prime ranking. The data suggest that while the proportions of men affected in each group are similar, the welders affected are absent slightly more often and while do not have longer spells than shipwrights and boilermakers they take longer to return than those controls who work in the cleanest environments.

It is considered that the null hypothesis is rejected.

Smoking, welding and absence

Tobacco smoking is known to cause respiratory diseases especially chronic bronchitis and bronchial carcinoma. If exposure to welding pollutants alone causes respiratory disease, in particular chronic bronchitis, one would expect to find an excess of absence attributed to respiratory disease where it was not expected, among the non-smokers of the welders. If smoking and welding pollutants act additively or synergistically an excess should be found in welders who smoked or have smoked over their controls.

These excesses should be demonstrated in indices of frequency as one should expect a higher proportion of welders to have a higher number of spells, and perhaps also in the severity of this absence. As age has been shown to exert a powerful influence on absence this factor must be considered when comparing indices in the three smoking habit categories. Thus all figures given below in this section are age standardised.

Among the non-smokers welders have the lowest frequency of absence attributed to all causes, all respiratory disease and upper respiratory tract diseases. For lower respiratory tract diseases the welders age standardised rate of new spells per 1000 man-years is exceeded by Control group 1 and equals that of Control group 2 and the inception rates differ only minimally being 3, 4 and 2% respectively. Thus there is no real evidence of excess absence among the non-smoking welders.

The picture is less clear cut among the smokers where there are slight excesses for welders, more in severity than frequency. For welders there is no excess frequency of absence attributed to all causes and indices of severity are very similar to those of Control group 1, though slightly greater than those of Control group 2 where the mean annual duration is 21.7 days (welders 24.1 days) and the mean length of spells 5.4 days (welders 6.5 days). When the data are restricted to absence attributed to all respiratory diseases welders have the greatest rate of new spells per 1000 man-years, 349 compared to 309 and 321 in the respective control groups but the proportion of men involved in these absences, as shown by the inception rates, are within the narrow range (22-25%), welders having the highest rate. The severity of absence hardly differs between groups. This pattern is repeated with respect to upper respiratory tract disease and in the indices of frequency of lower respiratory tract disease. In the latter case the mean length of spells of absence among welders (30 days) is very slightly greater than the control groups (28.6 and 25.1 days respectively). Thus, in summary, similar proportions of welders and controls who smoke take absence but when that absence is attributed to respiratory tract disease this proportion of welders take slightly more frequent and slightly longer spells than their controls. It is thought unlikely that such slight excesses indicate a separate clinically more severe illness attributable to exposure to welding pollutants, but probable that the symptoms related to absence are attributable to tobacco smoking the affected men deciding to take absence at an earlier stage in their symptoms than their controls and/or delaying their return until symptoms are more completely resolved as they are more susceptible to the irritating and thus aggravating effects of welding pollutants during acute respiratory disease.

Ex-smokers may have been prompted or forced to stop smoking by symptoms. If welders do suffer more respiratory disease and thus more respiratory symptoms one would expect to find proportionately more ex-smokers among welders than controls. This is not the case, in fact the converse situation was found. There is very slight excess frequency but not severity with respect to all respiratory disease and upper respiratory tract disease. This excess is more notable with respect to lower respiratory tract disease indicating a slightly higher proportion of welders (6% against 4% and 2%) take more spells than their controls but these spells are shorter than the controls and occur mainly in a younger group of welders. Thus it is concluded that while welding pollutants may prompt the men to have a lower threshold of non-attendance there is insufficient evidence to suggest that these are the cause of the symptoms.

5. CONCLUSIONS

Welders tend to be older than their controls, a higher proportion smoke and a lower proportion have never smoked.

Manpower movement, selective employment and medical discharge data show no evidence of an excess of respiratory ill-health among welders.

Sickness absence data show no substantial evidence to show that welding is related to all and respiratory disease absence except in smokers and ex-smokers where it is concluded that the presence of welding pollutants may prompt men with respiratory symptoms to take absence rather than being the cause of these symptoms.

REFERENCES

BEHREND, H. (1978)

How to monitor absence from work.

Institute of Personnel Management, London.

BUZZARD, R.B., and SHAW, W.J. (1952)

An analysis of absence under a scheme of paid sick leave.

Brit J Ind Med 9,282.

CARTWRIGHT, D., and ZANDER, A. (1968)

Group dynamics

Harper and Row, New York.

cited by Steers and Rhodes, 1978.

COE, J. (1955)

The physicians role in sickness absence certification : a reconsideration.

J O M 17,11,722.

FORTUIN, G.J. (1955)

Sickness absenteeism

Bull Wld Hlth Org 13,513.

FROGGAT, P. (1968)

Research in industrial morbidity : principles and opportunities.

Trans Soc Occup Med 18,89.

HEDGES, J.N. (1973)

Absence from work - a look at some national data.

Monthly Labour Review 96,24.

HILL, M. (1967)
Who stays Home?
New Society 9,459.

HODGKIN, K. (1970)
The general practitioner and industrial absenteeism.
Proc roy Soc Med 63,1134.

ISOMBERT-JAMATI, V. (1962)
Absenteeism among women workers in industry.
International Labour Review 85,248.

JEDRYCHOWSKI, W. (1976)
Sickness absence caused by chest diseases in relation to smoking and chronic bronchitis symptoms.
Brit J Ind Med 33,243.

KNOX, J.B. (1961)
Absenteeism and turnover
American Sociological Review 26,424

LOCKE, E.A. (1976)
The nature and causes of job satisfaction in M.D. Dunnette (Ed), Handbook of industrial and organisational psychology.
Rand McNally, Chicago, p 1297.

MARTIN, J. (1971)
Some aspects of absence in a light engineering factory.
Occupational Psychology 45,77.

METZER, H., and MANN, F. (1953)
Employee attitudes and absences.
Personnel Psychology, 6,467.

MILES, R.H., and PERREAULT, W.D. (1976)
Organisational role conflict : its antecedents and consequences.
Organisational behaviour and human performance, 17,19.

MOFFAT, J.S. (1970)
Some impressions of a Regional Medical Officer.
Proc Roy Soc Med 63,1150.

NICHOLSON, N., BROWN, C.A. and CHADWICK-JONES, J.K. (1976)
Absence from work and job satisfaction
Journal of Applied Psychology, 61,728.

NICHOLSON, N., and GOODGE, P.M. (1976)
The influence of social, organisational and biographical factors on female absence.
Journal of Management Studies 13,234.

PORTER, L.W., and STEERS, R.M. (1973)
Organisational, work and personal factors in employee turnover and absenteeism.
Psychological Bulletin 80,151.

SHAW, M.E. (1976)
Group dynamics
McGraw-Hill, New York.
cited by Steers and Rhodes.

SMITH, F.J. (1977)
Work attitudes as predictors of specific day attendance.
J. Appl Psychol 62,16.

STEERS, R.M., and RHODES, S.R. (1978)
Major influences on employee attendance : a process modal
University of Oregon Report N00014 - 76 - C - 0164.

STOCKFORD, L.O. (1944)
Chronic absenteeism and good attendance.
Personnel Journal 23,202.

TAYLOR, P.J. (1976)
Occupational and regional associations of death, disablement and sickness absence among Post Office staff 1972-75.
Brit J Ind Med 33,230.

VROOM, V. (1964)
Work and Motivation
Wiley, New York
cited by Steers and Rhodes, 1978.

WHITEHEAD, F.E. (1972)
Recent trends in certificated sickness absence.
Proc roy Soc Med 65,567.

TABLE A1 Number of subjects in welders and *control* groups *1 and 2 in Dockyard Employed*, *Discharged and Combined* Populations and man-years at risk in Combined Population for each and all Yards, and average man-years/man in all Yards.

Group	Subjects in Employed Population				Subjects in Discharged Population				Combined Population								Average man-years/man
									Subjects				Man-years				
	D*	P*	R*	All	D*	P*	R*	All	D*	P*	R*	All	D*	P*	R*	All	All
Welders	221	144	59	424	53	31	25	109	274	175	84	533	1196	763	312	2271	4.3
Control 1	528	255	162	945	171	157	79	407	699	412	241	1352	2845	1468	825	5138	3.8
Control 2	555	439	347	1341	241	332	253	826	796	771	600	2167	2900	2590	1826	6893	3.2
All	1304	838	568	2710	465	520	357	1342	1769	1358	925	4052	6941	4821	2963	14302	3.5

*NOTE: D = Devonport, P = Portsmouth and R = Rosyth

TABLE A2 Manpower reduction during first four years of survey period among welders and control groups in Dockyard Combined Population

Group	Number employed on first day	Number employed on last day	Change	
			Number	%
Welders	473	439	-34	-7.2%
Control 1	1096	960	-136	-12.4%
Control 2	1558	1431	-127	-8.1%

TABLE A3 Relative and absolute age frequency distribution of welders and control groups 1 and 2 in Dockyard Combined Population

Group	Age (years)					Mean age (No. of men)
	<25	25-34	35-44	45-54	>54	
Welders	13.1 (70)	8.4 (45)	20.5 (109)	31.7 (169)	26.3 (140)	44.8 (533)
Control 1	20.8 (281)	27.4 (371)	20.8 (281)	17.1 (231)	13.9 (188)	37.5 (1352)
Control 2	25.0 (541)	18.9 (410)	16.1 (348)	13.3 (288)	26.8 (580)	40.1 (2167)
Boilermakers	20.3 (105)	25.5 (132)	20.7 (107)	16.2 (84)	17.2 (89)	38.5 (517)
Shipwrights	21.1 (176)	28.6 (239)	20.8 (174)	17.6 (147)	11.9 (99)	37.0 (835)
Electrical fitters	36.0 (360)	26.0 (260)	11.2 (112)	10.4 (104)	16.3 (163)	34.8 (999)
Painters	15.6 (63)	17.4 (70)	26.1 (105)	15.6 (63)	25.3 (102)	41.9 (403)
Joiners	15.4 (118)	10.5 (80)	17.1 (131)	15.8 (121)	41.2 (315)	46.0 (765)

TABLE A4 Relative (and absolute) age frequency distribution of welders and control groups in Dockyard Discharged Population

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	18.3 (20)	6.4 (7)	4.6 (5)	20.2 (22)	50.5 (55)
Control 1	24.3 (99)	27.8 (113)	10.8 (44)	9.1 (37)	28.0 (114)
Control 2	24.7 (204)	21.7 (179)	8.9 (74)	7.0 (58)	37.7 (311)

TABLE A5 Number and percentage of married men in welders and control groups in Dockyard Combined Population

Group	Married men	
	Number	Percentage of group
Welders	413	77.5
Control 1	982	72.6
Boilermakers	388	75.0
Shipwrights	594	71.1
Control 2	1411	65.1
Electrical fitters	559	56.0
Painters	305	75.7
Joiners	547	71.5

TABLE A 6 Percentage (and number) of men in welders and control groups for whom a smoking history is available related to age

Group	Age (years)					
	<25	25-34	35-44	45-54	>54	All ages
Welders	88.6 (62)	88.9 (40)	95.4 (104)	90.5 (154)	88.6 (124)	90.8 (484)
Control 1	88.6 (249)	85.7 (318)	94.7 (266)	90.9 (210)	86.2 (162)	89.1 (1205)
Control 2	86.1 (466)	84.6 (347)	89.4 (311)	87.8 (253)	88.1 (511)	87.1 (1888)

TABLE A7 Mean age of men for which a smoking history is available (responders) and not available (non-responders) in welders and control groups in Dockyard Combined Population

Group	Mean age (years)	
	Responders	Non-responders
Welders	44.7	46.4
Control 1	37.5	38.1
Control 2	40.3	38.9

TABLE A 8 Percentage (and number) of welders and controls in each smoking habit category in Dockyard Combined Population for whom smoking habit is known in each smoking category

Group	Percentage and number of men			
	Non-smokers	Smokers	Ex-smokers	All categories
Welders	20.7 (100)	60.3 (292)	19.0 (92)	100.0 (484)
Control 1	25.8 (311)	53.7 (647)	20.5 (247)	100.0 (1205)
Control 2	27.4 (518)	54.2 (1023)	18.4 (347)	100.0 (1888)

TABLE A 9 Percentage (and number) of welders and controls in each smoking habit category expressed as man-years in Dockyard Combined Population for whom smoking habit is known in each smoking category

Group	Percentage of man-years for which information is available	Percentage (and number) of man years		
		Non-smokers	Smokers	Ex-smokers
Welders	92.6	20.9 (439.4)	58.5 (1230.8)	20.6 (423.3)
Control 1	93.7	24.7 (1183.1)	51.5 (2470.8)	23.8 (1140.7)
Control 2	89.9	25.6 (1685.4)	53.2 (3504.4)	21.2 (1400.3)

TABLE A 10 Percentage (and number) of welders and controls in the Employed Populations at Devonport (D), Portsmouth (P), and Rosyth (R) for whom information is available about journey to work related to length of that journey

Yard	Group	Length (miles) of journey					Number for whom information is available	% all in Group
		<2	2 to 3	4 to 5	6 to 9	>9		
D	Welders	16.3 (32)	31.1 (61)	28.1 (55)	21.9 (43)	2.5 (5)	196	88.7
	Control 1	11.9 (59)	33.7 (167)	26.9 (133)	21.4 (106)	6.1 (30)	495	93.8
	Control 2	14.2 (73)	34.5 (177)	24.2 (124)	20.8 (107)	6.2 (32)	513	92.4
P	Welders	12.6 (16)	48.8 (62)	17.3 (22)	10.2 (13)	11.0 (14)	127	88.2
	Control 1	10.5 (25)	43.0 (102)	15.2 (36)	18.6 (44)	12.7 (30)	237	92.9
	Control 2	7.0 (27)	45.3 (174)	17.2 (66)	18.4 (71)	12.0 (46)	384	87.5
R	Welders	5.5 (3)	29.6 (16)	22.2 (12)	9.3 (5)	33.3 (18)	54	91.5
	Control 1	5.6 (8)	26.8 (38)	20.4 (29)	5.6 (8)	41.5 (59)	142	87.7
	Control 2	4.2 (13)	26.5 (82)	21.7 (67)	13.3 (41)	34.3 (106)	309	89.0

TABLE A11 Percentage (and number) of welders and controls in the Employed Populations at Devonport (D), Portsmouth (P) and Rosyth (R) for whom information on journey to work is available related to mode of transport to work

Yard	Group	Mode of transport				Number for whom information is available	% Total
		Walk or cycle	Bus	Car or Motor cycle	Other		
D	Welders	21.4 (42)	32.7 (64)	44.9 (88)	1.0 (2)	196	88.7
	Control 1	24.4 (120)	22.8 (112)	51.8 (255)	1.0 (5)	492	93.2
	Control 2	23.2 (119)	24.4 (125)	51.5 (264)	1.0 (5)	513	92.4
P	Welders	52.7 (67)	13.4 (17)	30.7 (39)	3.1 (4)	127	88.2
	Control 1	50.8 (120)	14.0 (33)	34.3 (81)	4.2 (2)	236	92.5
	Control 2	42.8 (172)	17.4 (70)	38.3 (154)	1.5 (6)	402	91.6
R	Welders	11.1 (6)	38.9 (21)	48.1 (26)	1.8 (1)	54	91.5
	Control 1	16.6 (24)	33.3 (48)	43.8 (63)	6.2 (9)	144	88.9
	Control 2	8.3 (27)	43.8 (142)	43.5 (141)	4.3 (14)	324	93.4

TABLE A 12 Indices of frequency and severity of certificated absence related to the length of journey to work in Employed Population in Dockyard Combined Population

Index	Length (miles) of journey				
	<2	2 to 3	4 to 5	6 to 9	>9
New spells/1000 man years	822	758	841	770	919
Inception rate/100 persons	45	45	46	44	47
Mean annual duration (days)	15.6	14.9	18.5	14.4	18.3
Mean length of spells (days)	19.0	19.6	22.0	18.6	19.9

TABLE A 13 Indices of frequency and severity of certificated absence related to the mode of transport used to travel to work in Employed Population in Dockyard Combined Population

Index	Walk or cycle	Bus	Car or motor cycle
New spells/1000 man years	740	862	810
Inception rate/100 persons	43	46	46
Mean annual duration (days)	14.1	18.3	15.8
Mean length of spells (days)	19.1	21.1	19.5

TABLE A14 Number and percentage of men in welders and control groups in the Devonport Employed Population who have been placed in restricted employment for medical reasons showing system involved in the injury or disease prompting that action

System involved in main cause of discharge or death	Welders n = 221		Control 1 n = 528		Control 2 n = 555	
	No. of men	% total at risk	No. of men	% total at risk	No. of men	% total at risk
Respiratory (not asbestos related	2	0.9	1	0.2	4	0.7
Cardiovascular	8	3.6	4	0.8	8	1.4
Gastrointestinal	3	1.4	3	0.6	4	0.7
Musculoskeletal	13	5.9	14	2.7	4	0.7
CNS and psychiatric	4	1.8	2	0.4	2	0.4
Skin and eyes	2	0.9	6	1.1	4	0.7
All systems	32	14.5	30	5.7	26	4.7
Minor asbestos related lesions	2	0.9	10	1.9	2	0.4

TABLE A 15 Medical discharges and deaths while still in employment in men aged 39 years and over in all three Dockyards

System involved in main cause of discharge or death	Welders n = 379		Control 1 n = 540		Control 2 n = 1085	
	No. of men	% total at risk	No. of men	% total at risk	No. of men	% total at risk
Respiratory	2	0.5	14	2.6	24	2.2
Cardiovascular	14	3.7	31	5.7	47	4.3
Gastrointestinal	2	0.5	5	0.9	3	0.3
Urinogenital	-	-	-	-	3	0.3
Endocrine	-	-	-	-	2	0.2
Musculoskeletal	3	0.8	10	1.8	9	0.8
CNS and psychiatric	1	0.3	2	0.4	8	0.7
Other - including accidents	1	0.3	5	0.9	5	0.5
All systems	23	6.1	67	12.4	101	9.3
Mean age (years) at death or medical discharge	57.6		54.5		59.7	

TABLE A 16 Percentage (and number) of spells of absence attributed to respiratory disease which started on each day of week

Group	Percentage and number of spells starting on stated day						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Welders	1.3 (6)	42.2 (198)	19.4 (91)	15.4 (72)	9.1 (43)	8.3 (39)	4.3 (20)
Control 1	0.9 (10)	39.0 (439)	20.9 (236)	15.9 (179)	11.0 (124)	7.4 (83)	4.9 (55)
Control 2	1.3 (16)	36.9 (447)	19.5 (236)	15.5 (188)	11.6 (141)	10.0 (121)	5.2 (63)

TABLE A 17 New spells of absence attributed to all causes (certificated and uncertificated) per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	7396	3778	3429	2451	2119
Control 1	8172	4526	3668	2827	2190
Control 2	8064	4895	3476	2593	2149

TABLE A 18 Crude and standardised rates of new spells of absence attributed to all causes (certificated and uncertificated) per 1000 man-years in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised Rates		
		Age	Smoking habit	Age and smoking
Welders	3189	3631	3227	3561
Control 1	4256	4055	4239	4049
Control 2	4030	4012	4017	4008

TABLE A 19 Crude rates of new spells of absence attributed to all causes (certificated and uncertificated) per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Crude rates			
	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	2892	3321	2929	3660
Control 1	4505	4165	4255	4062
Control 2	4504	4065	3313	4162

TABLE A 20 Age standardised rates of new spells of absence attributed to all causes (certificated and uncertificated) per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Age standardised rates			
	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	3582	3650	3149	4049
Control 1	4465	3961	3897	3779
Control 2	4276	4074	3498	4137

TABLE A 21 Inception rate per 100 persons for absence attributed to all causes (certificated and uncertificated) in welders and controls in Dockyard Combined Population related to age.

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	62	41	45	41	50
Control 1	73	52	45	40	47
Control 2	55	49	43	38	42

TABLE A 22 Crude and standardised inception rate per 100 persons for absence attributed to all causes (certificated and uncertificate in welders and controls in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	43	45	44	44
Control 1	50	49	50	49
Control 2	45	45	45	45

TABLE A 23 Crude inception rates per 100 persons for absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	36	46	42	47
Control 1	50	48	52	52
Control 2	44	47	41	48

TABLE A 24 Age standardised inception rate per 100 persons for absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	39	46	43	45
Control 1	50	49	50	50
Control 2	43	47	41	48

TABLE A 25 Mean annual duration (days) of absence attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	33.4	13.2	19.9	20.7	22.5
Control 1	31.5	20.6	19.8	18.4	28.6
Control 2	22.1	18.6	18.6	18.0	26.7

TABLE A 26 Crude and standardised mean annual duration (days) of absence attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised Rates		
		Age	Smoking habit	Age and smoking
Welders	21.5	21.3	21.4	20.8
Control 1	22.4	23.3	22.4	23.1
Control 2	21.3	20.7	21.2	20.6

TABLE A.27 Crude mean annual duration (days) of absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	14.8	24.2	17.7	28.8
Control 1	19.6	23.0	23.2	25.6
Control 2	18.7	22.4	18.8	26.5

TABLE A 28 Age standardised mean annual duration (days) of absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	15.3	24.1	17.1	24.0
Control 1	20.4	24.1	22.5	25.9
Control 2	18.1	21.7	18.4	26.3

TABLE A29 Mean length of spell (days) of absence (and number of spells) attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population related to age.

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	4.5 (1617)	3.5 (715)	5.8 (1780)	8.5 (2087)	10.6 (1044)
Control 1	3.9 (6191)	4.6 (6943)	5.4 (4562)	6.5 (2933)	13.0 (1234)
Control 2	2.7 (10502)	3.8 (6511)	5.4 (4754)	6.9 (3524)	12.4 (4204)

TABLE A 30 Crude and standardised mean length of spell (days) of absence attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	6.8	5.8	6.6	5.7
Control 1	5.3	5.7	5.3	5.7
Control 2	5.3	5.2	5.3	5.2

TABLE A 31 Crude mean length of spells (days) of absence (and number of spells) attributed to all causes (certificated and uncertificated) in non-smokers, smokers, and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	5.1 (1271)	7.3 (4088)	6.1 (1266)	7.9 (618)
Control 1	4.4 (5331)	5.5 (10290)	5.4 (4854)	6.3 (1388)
Control 2	4.2 (7591)	5.5 (14270)	5.7 (4639)	6.4 (2995)

TABLE A 32 Age standardised mean length of spells (days) of absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	4.2	6.5	5.4	5.5
Control 1	4.6	6.1	5.7	6.5
Control 2	4.3	5.4	5.2	6.5

TABLE A 33 New spells of absence attributed to all respiratory diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	< 25	25-34	35-44	45-54	> 54
Welders	608	306	306	233	223
Control 1	663	330	277	237	188
Control 2	531	379	290	224	225

TABLE A 34 Crude and standardised rates of new spells of absence attributed to all respiratory diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	290	320	292	307
Control 1	332	321	330	320
Control 2	319	318	316	316

TABLE A 35 Crude rates of new spells of absence attributed to all respiratory diseases per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	200	332	268	266
Control 1	318	319	366	357
Control 2	314	324	242	460

TABLE A.36 Age standardised rates of new spells of absence attributed to all respiratory diseases per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	242	349	296	285
Control 1	326	309	329	348
Control 2	304	321	254	459

TABLE A 37 Inception rate per 100 persons for absence attributed to all respiratory diseases in welders and controls in Dockyard Combined Population related to age

Group	Age (years)				
	< 25	25-34	35-44	45-54	> 54
Welders	37	24	22	19	19
Control 1	44	25	22	18	16
Control 2	35	27	20	16	18

TABLE A 38 Crude and standardised inception rate per 100 persons for absence attributed to all respiratory diseases in welders and controls in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	22	23	22	23
Control 1	25	24	24	24
Control 2	22	22	22	22

TABLE A 39 Crude inception rates per 100 persons for absence attributed to all respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	16	24	21	22
Control 1	22	24	27	24
Control 2	22	23	19	27

TABLE A 40 Age standardised inception rate per 100 persons for absence attributed to all respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	18	25	23	22
Control 1	23	23	25	23
Control 2	22	22	20	27

TABLE A 41 Mean annual duration (days) of absence attributed to all respiratory diseases in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	> 54
Welders	7.2	3.3	5.1	5.0	5.8
Control 1	7.5	5.2	4.8	3.6	5.3
Control 2	5.2	4.5	5.0	3.9	6.0

TABLE A 42 Crude and standardised mean annual duration (days) of absence attributed to all respiratory diseases in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	5.3	5.2	5.2	5.0
Control 1	5.1	5.1	5.1	5.1
Control 2	5.0	4.9	5.0	4.9

TABLE A.43 Crude mean annual duration (days) of absence attributed to all respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	3.4	6.5	3.5	5.7
Control 1	4.2	5.3	5.2	6.7
Control 2	4.2	5.6	3.7	7.0

TABLE A 44 Age standardised mean annual duration (days) of absence attributed to all respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	3.3	6.4	3.5	5.5
Control 1	4.6	5.2	4.7	7.0
Control 2	4.1	5.3	3.7	6.9

TABLE A 45 Mean length of spell (days) of absence (and number of spells) attributed to all respiratory diseases in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	< 25	25-34	35-44	45-54	> 54
Welders	11.9 (133)	10.7 (58)	16.6 (159)	21.7 (198)	26.0 (110)
Control 1	11.3 (502)	15.6 (506)	17.4 (344)	15.2 (246)	28.1 (106)
Control 2	9.9 (691)	11.9 (504)	17.3 (396)	17.5 (305)	26.8 (440)

TABLE A 46 Crude and standardised mean length of spell (days) of all respiratory diseases in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	18.2	16.0	18.0	15.7
Control 1	15.4	16.4	15.6	16.5
Control 2	15.8	15.3	15.8	15.4

TABLE A 47 Crude mean length of spells (days) of absence (and number of spells) attributed to all respiratory diseases in non-smokers, smokers, and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	16.8 (88)	19.7 (409)	13.0 (116)	21.5 (45)
Control 1	13.3 (376)	16.5 (788)	14.3 (418)	18.8 (122)
Control 2	13.5 (529)	17.2 (1137)	15.2 (339)	15.1 (331)

TABLE A 48 Age standardised mean length of spells (days) of absence attributed to all respiratory disease in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	13.0	18.0	11.5	20.2
Control 1	14.0	17.2	14.1	22.4
Control 2	13.5	16.7	14.4	14.6

TABLE A.49 New spells of absence attributed to upper respiratory tract diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	< 25	25–34	35–44	45–54	>54
Welders	535	264	270	176	148
Control 1	586	290	228	195	119
Control 2	486	341	249	184	163

TABLE A 50 Crude and standardised rates of new spells of absence attributed to upper respiratory tract diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	233	264	236	252
Control 1	281	267	279	266
Control 2	273	273	270	271

TABLE A 51 Crude rates of new spells of absence attributed to upper respiratory tract diseases per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	171	271	213	172
Control 1	275	264	318	281
Control 2	283	268	213	273

TABLE A.52 Age standardised rates of new spells of absence attributed to upper respiratory tract diseases per 1000 man-years in non-smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	210	287	239	205
Control 1	281	250	282	282
Control 2	278	269	223	388

TABLE A 53 Inception rate per 100 persons for absence attributed to upper respiratory tract diseases in welders and controls in Dockyard Combined Population related to age

Group	Age (years)				
	< 25	25-34	35-44	45-54	> 54
Welders	35	22	19	15	13
Control 1	42	23	19	16	11
Control 2	33	25	18	14	14

TABLE A 54 Crude and standardised inception rate per 100 persons for absence attributed to upper respiratory tract diseases in welders and controls in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	18	20	18	19
Control 1	22	21	22	21
Control 2	20	20	20	20

TABLE A 55 Crude inception rates per 100 persons for absence attributed to upper respiratory tract diseases in non-smokers, smokers, and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	14	20	18	14
Control 1	20	21	24	22
Control 2	21	19	17	24

TABLE A 56 Age standardised inception rate per 100 persons for absence attributed to upper respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	17	21	19	15
Control 1	21	20	22	21
Control 2	20	19	18	24

TABLE A 57 Mean annual duration (days) of absence attributed to upper respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	6.3	2.7	3.6	3.8	3.3
Control 1	6.6	4.6	3.1	2.7	2.1
Control 2	4.7	4.1	4.2	3.2	3.6

TABLE A 58 Crude and standardised mean annual duration (days) of absence attributed to upper respiratory tract diseases in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	3.8	3.8	3.7	3.6
Control 1	3.9	3.7	3.8	3.6
Control 2	3.9	3.9	3.9	3.9

TABLE A 59 Crude mean annual duration (days) of absence attributed to upper respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	2.7	4.8	2.6	2.8
Control 1	3.5	3.8	4.2	4.5
Control 2	3.7	4.0	3.1	5.3

TABLE A 60 Age standardised mean annual duration (days) of absence attributed to upper respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	2.7	4.6	2.6	2.8
Control 1	3.7	3.5	3.7	4.2
Control 2	3.6	4.1	3.1	5.3

TABLE A.61 Mean length of spell (days) of absence (and number of spells) attributed to upper respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	11.7 (117)	10.2 (50)	13.4 (140)	21.5 (150)	22.2 (73)
Control 1	11.2 (444)	15.7 (445)	13.7 (283)	13.7 (202)	18.0 (67)
Control 2	9.7 (633)	12.0 (453)	16.7 (340)	17.1 (250)	22.0 (318)

TABLE A 62 Crude and standardised mean length of spell (days) of upper respiratory tract diseases in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	16.2	14.3	15.9	13.9
Control 1	13.8	13.9	13.9	13.9
Control 2	14.3	14.1	14.3	14.3

TABLE A 63 Crude mean length of spells (days) of absence (and number of spells) attributed to upper respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	15.6 (75)	17.5 (334)	12.0 (92)	16.0 (29)
Control 1	12.8 (325)	14.3 (652)	13.3 (363)	15.1 (101)
Control 2	13.1 (477)	15.0 (939)	14.4 (298)	13.7 (280)

TABLE A 64 Age standardised mean length of spells (days) of absence attributed to upper respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	12.2	16.2	10.9	15.1
Control 1	13.3	14.3	12.8	15.3
Control 2	13.1	15.0	13.9	13.3

TABLE A 65 New spells of absence attributed to lower respiratory tract diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	73	42	37	56	75
Control 1	77	40	49	42	69
Control 2	45	38	41	40	62

TABLE A 66 Crude and standardised rates of new spells of absence attributed to lower respiratory tract diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	56	56	57	55
Control 1	51	54	51	54
Control 2	47	45	46	45

TABLE A 67 Crude rates of new spells of absence attributed to lower respiratory tract diseases per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	30	61	56	95
Control 1	43	55	48	61
Control 2	31	56	29	71

TABLE A 68 Age standardised rates of new spells of absence attributed to lower respiratory tract diseases per 1000 man-years in non-smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	31	62	57	81
Control 1	45	59	47	66
Control 2	31	53	31	71

TABLE A.69 Inception rate per 100 persons for absence attributed to lower respiratory tract diseases in welders and controls in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	5	4	4	5	6
Control 1	6	4	4	3	4
Control 2	3	3	3	3	5

TABLE A 70 Crude and standardised inception rate per 100 persons for absence attributed to lower respiratory tract diseases in welders and controls in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	5	5	5	5
Control 1	4	4	4	4
Control 2	4	4	4	4

TABLE A71 Crude inception rates per 100 persons for absence attributed to lower respiratory tract diseases in non-smokers, smokers, and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	2	5	5	9
Control 1	4	4	4	4
Control 2	2	5	3	5

TABLE A72 Age standardised inception rate per 100 persons for absence attributed to lower respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	3	5	6	8
Control 1	4	5	4	3
Control 2	2	4	3	4

TABLE A73 Mean annual duration (days) of absence attributed to lower respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	1.0	0.6	1.5	1.3	2.5
Control 1	0.9	0.6	1.7	0.9	3.2
Control 2	0.6	0.4	0.9	0.8	2.5

TABLE A74 Crude and standardised mean annual duration (days) of absence attributed to lower respiratory tract diseases in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	1.5	1.4	1.5	1.4
Control 1	1.3	1.5	1.3	1.5
Control 2	1.1	1.0	1.1	1.0

TABLE A75 Crude mean annual duration (days) of absence attributed to lower respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	0.7	1.8	0.9	3.0
Control 1	0.7	1.5	1.0	2.3
Control 2	0.5	1.5	0.6	1.6

TABLE A76 Age standardised mean annual duration (days) of absence attributed to lower respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	0.6	1.7	0.8	2.6
Control 1	0.9	1.7	1.0	2.8
Control 2	0.5	1.3	0.6	1.6

TABLE A 77 Mean length of spell (days) of absence (and number of spells) attributed to lower respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	13.4 (16)	14.0 (8)	40.2 (19)	22.4 (48)	33.5 (37)
Control 1	12.0 (58)	14.6 (61)	34.3 (61)	21.9 (44)	45.6 (39)
Control 2	12.4 (58)	10.7 (51)	21.3 (56)	19.3 (55)	39.3 (122)

TABLE A 78 Crude and standardised mean length of spell (days) of lower respiratory tract diseases in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	26.6	25.7	26.5	25.3
Control 1	24.4	27.6	25.4	28.0
Control 2	24.3	22.4	23.9	21.8

TABLE A.79 Crude mean length of spells (days) of absence (and number of spells) attributed to lower respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	24.1 (13)	29.1 (75)	16.8 (24)	31.4 (16)
Control 1	16.7 (51)	26.8 (136)	21.1 (55)	36.8 (21)
Control 2	16.3 (52)	27.3 (198)	21.4 (41)	23.2 (51)

TABLE A 80 Age standardised mean length of spells (days) of absence attributed to lower respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	20.5	30.0	12.9	30.6
Control 1	18.3	28.6	21.0	49.8
Control 2	16.6	25.1	18.7	21.4

TABLE A 81 New spells of absence attributed to diseases other than respiratory per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	805	407	464	391	343
Control 1	1152	626	470	394	525
Control 2	713	528	527	405	447

TABLE A 82 Crude and standardised rates of new spells of absence attributed to diseases other than respiratory per 1000 man-years in welders and control groups in Dockyard Combined Population related to age.

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	439	464	443	451
Control 1	608	602	607	603
Control 2	516	513	515	512

TABLE A 83 Crude rates of new spells of absence attributed to diseases other than respiratory per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	357	477	398	474
Control 1	648	593	582	664
Control 2	472	546	448	609

TABLE A 84 Age standardised rates of new spells of absence attributed to diseases other than respiratory per 1000 man-years in non-smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	410	489	462	452
Control 1	658	591	557	625
Control 2	459	547	450	600

TABLE A 85 Inception rate per 100 persons for absence attributed to disease other than respiratory in welders and controls in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	48	28	34	29	26
Control 1	59	38	31	28	37
Control 2	38	34	32	29	31

TABLE A 86 Crude and standardised inception rate per 100 persons for absence attributed to diseases other than respiratory in welders and controls in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	31	32	31	31
Control 1	37	37	37	37
Control 2	32	32	32	32

TABLE A 87 Crude inception rates per 100 persons for absence attributed to diseases other than respiratory in non-smokers, smokers, and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	28	32	30	30
Control 1	38	36	38	38
Control 2	31	34	30	33

TABLE A 88 Age standardised inception rate per 100 persons for absence attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	31	31	30	29
Control 1	38	36	37	36
Control 2	31	34	30	33

TABLE A 89 Mean annual duration (days) of absence attributed to diseases other than respiratory in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	< 25	25-34	35-44	45-54	> 54
Welders	20.2	6.7	11.9	13.6	14.9
Control 1	17.5	11.9	12.0	12.4	21.4
Control 2	10.3	10.4	10.7	11.8	19.0

TABLE A.90 Crude and standardised mean annual duration (days) of absence attributed to diseases other than respiratory in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	13.6	13.1	13.5	12.8
Control 1	13.8	14.8	13.9	14.7
Control 2	13.0	12.5	12.9	12.5

TABLE A 91 Crude mean annual duration (days) of absence attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	9.0	15.0	11.7	20.0
Control 1	11.9	14.3	14.6	15.8
Control 2	10.7	13.6	12.4	16.3

TABLE A.92 Age standardised mean annual duration (days) of absence attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	8.9	14.7	10.9	15.0
Control 1	12.0	15.7	14.7	15.9
Control 2	10.4	13.1	11.8	16.2

TABLE A 93 Mean length of spell (days) of absence (and number of spells) attributed to diseases other than respiratory in welders and control groups in Dockyard Combined Population related to age

Group	Age (years)				
	<25	25-34	35-44	45-54	>54
Welders	25.1 (176)	16.5 (77)	25.7 (241)	34.8 (333)	43.3 (169)
Control 1	15.2 (873)	18.9 (960)	25.5 (584)	31.5 (409)	40.7 (296)
Control 2	14.5 (929)	19.6 (703)	20.3 (721)	29.0 (551)	42.5 (874)

TABLE A 94 Crude and standardised mean length of spell (days) attributed to diseases other than respiratory in welders and control groups in Dockyard Combined Population

Group	Crude rate	Standardised rates		
		Age	Smoking habit	Age and smoking
Welders	30.9	28.0	30.5	27.5
Control 1	22.8	25.0	23.0	24.7
Control 2	25.2	23.9	25.2	24.0

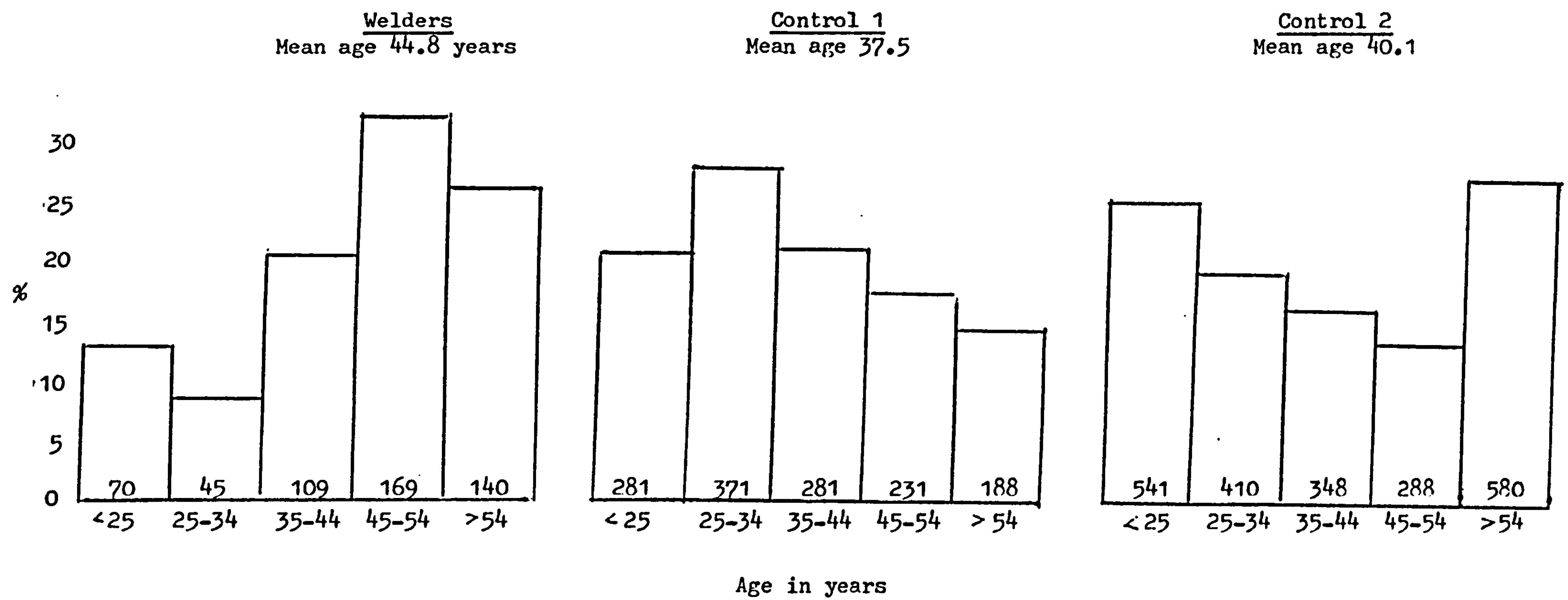
TABLE A 95 Crude mean length of spells (days) of absence (and number of spells) attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	25.1 (157)	31.4 (587)	29.4 (172)	42.1 (80)
Control 1	18.1 (767)	25.0 (1464)	24.2 (664)	23.7 (227)
Control 2	22.7 (796)	27.6 (1917)	25.0 (627)	26.8 (438)

TABLE A 96 Age standardised mean length of spells (days) of absence attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

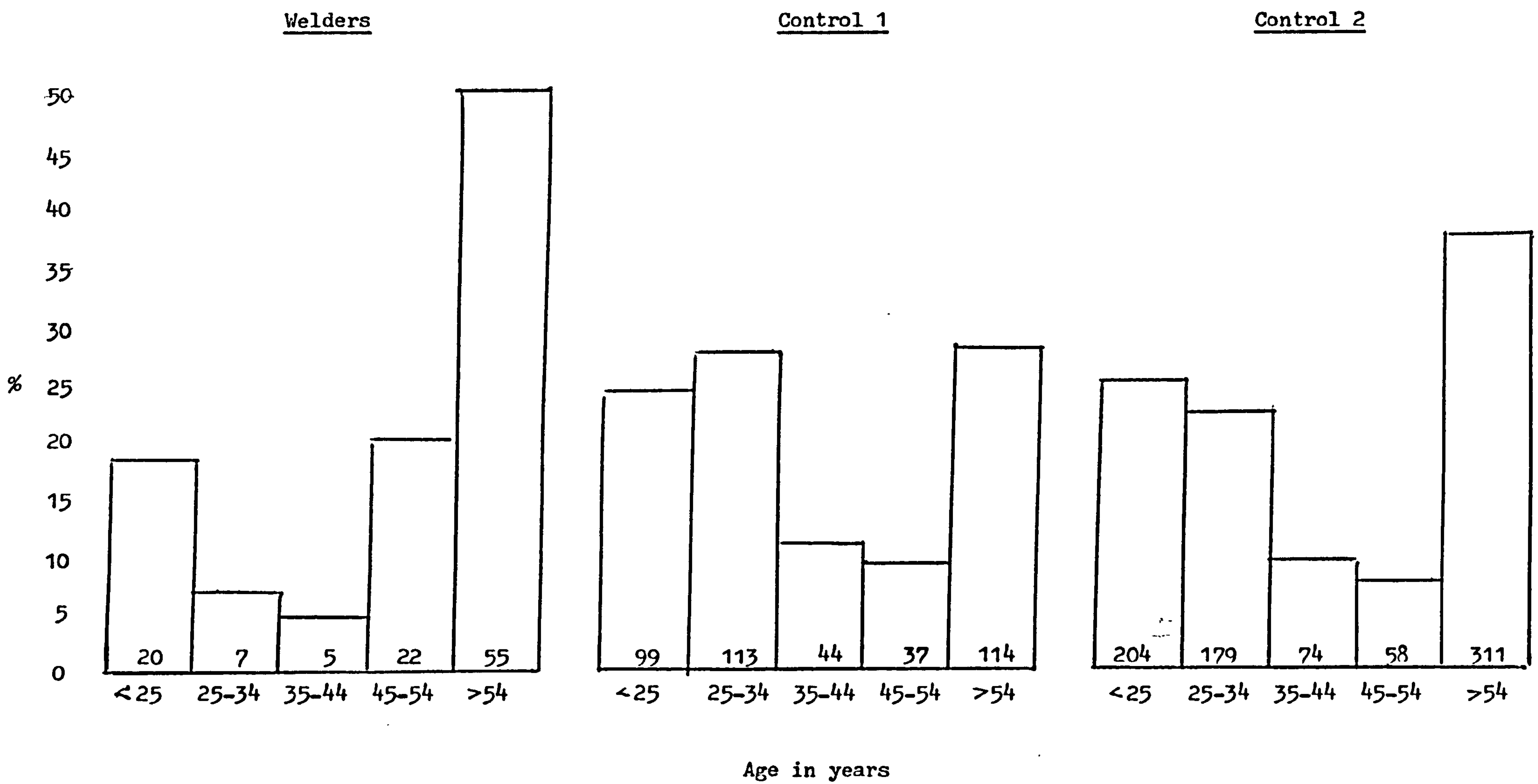
Group	Non-smokers	Smokers	Ex-smokers	Undefined
Welders	21.6	30.0	25.7	29.0
Control 1	18.9	26.7	26.5	23.9
Control 2	21.8	23.7	25.3	27.7

FIGURE A 1 Relative and absolute age frequency distributions of welders and control groups in Dockyard Combined Population



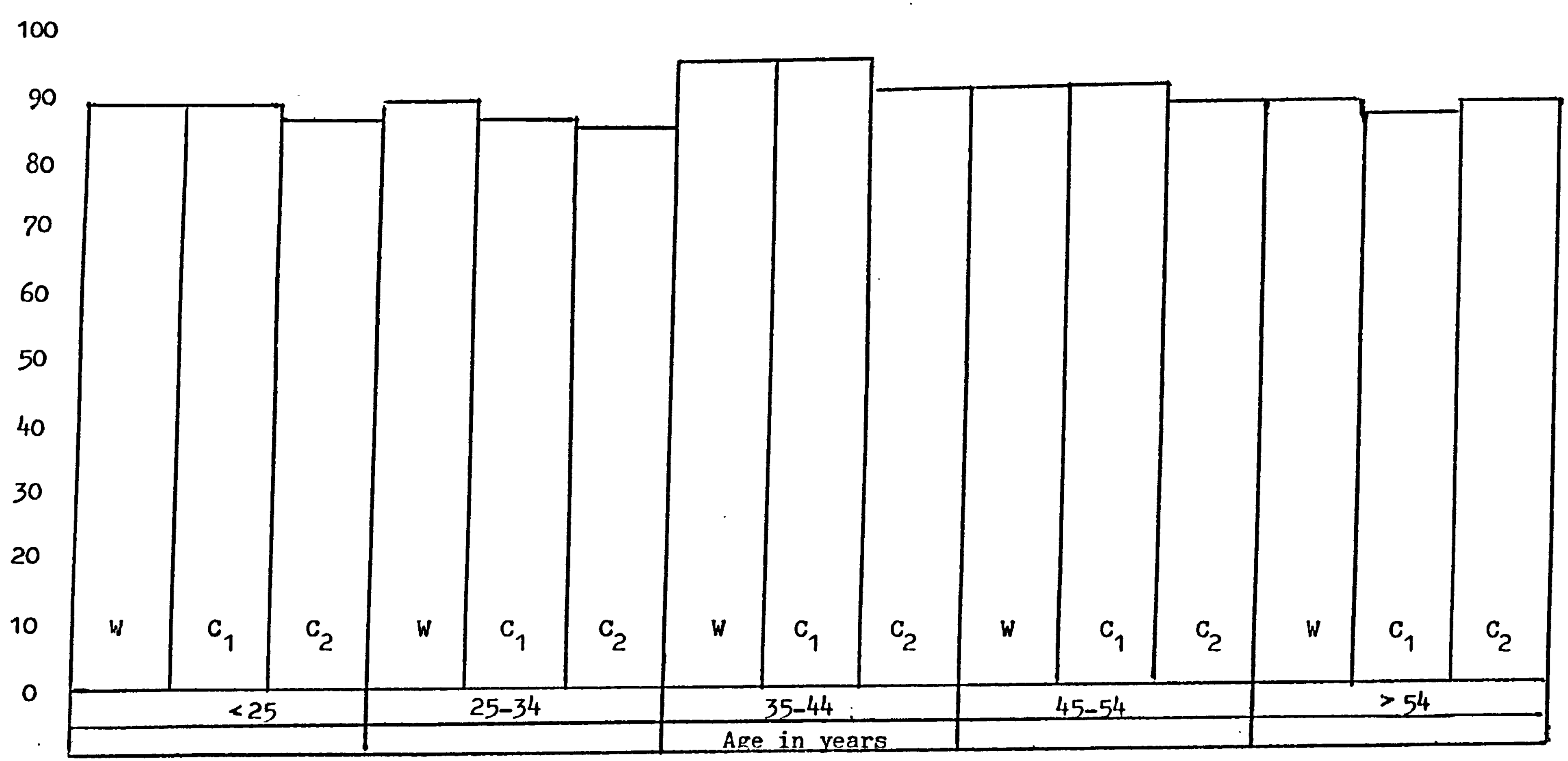
NOTE: Figures in each column refer to number of men

FIGURE A 2 Relative and absolute age frequency of welders and control groups in Dockyard Discharged Population



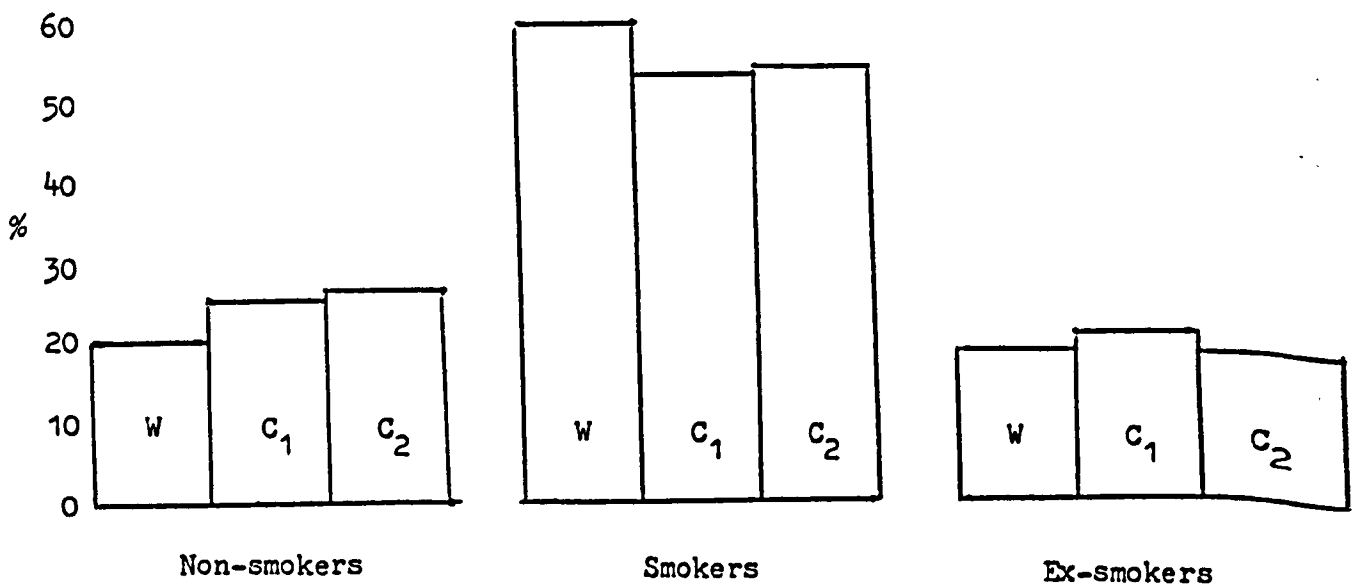
NOTE: Figures in each column refer to number of men

FIGURE A3 Relative age frequency distribution of welders and control groups in Dockyard Combined Population for whom a smoking history is available



W = Welders C_1 = Control group 1 C_2 = Control group 2

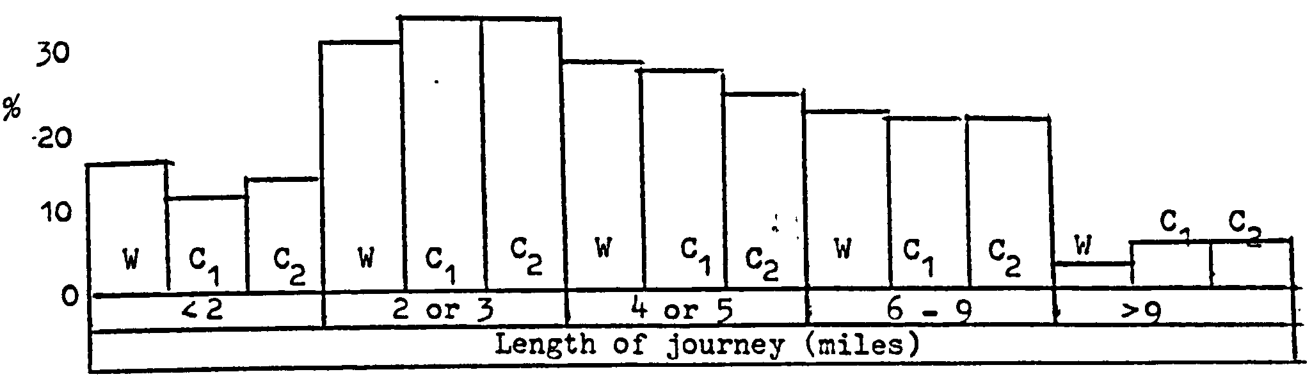
FIGURE A4 Percentage of welders and controls for whom smoking habit is known in each smoking category



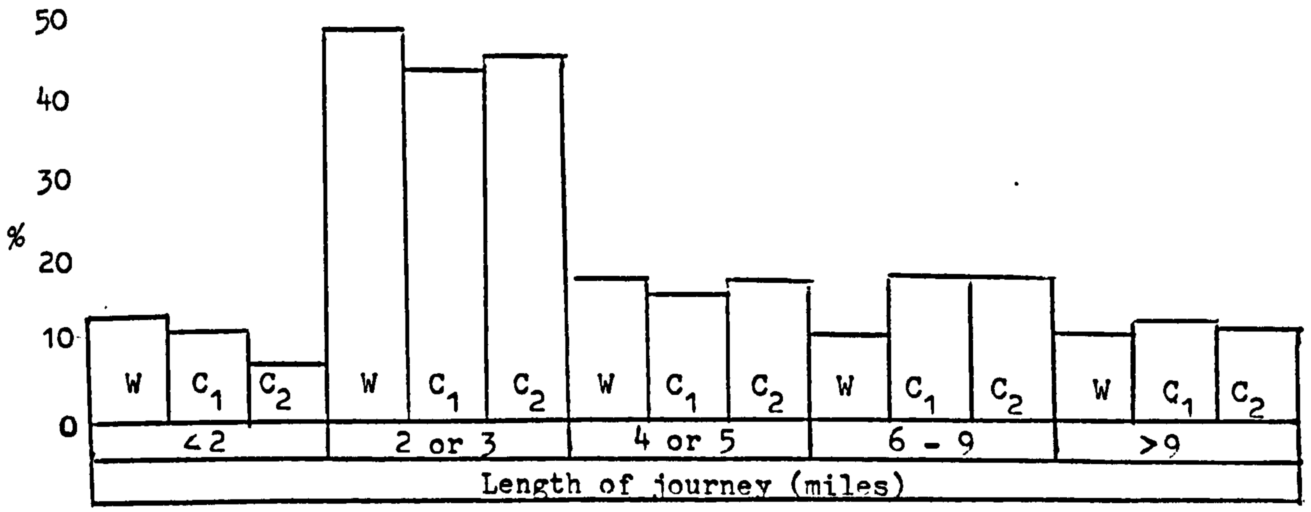
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 5 Percentage of men in welders and controls in each Dockyard with various lengths of journey to work

Devonport



Portsmouth



Rosyth

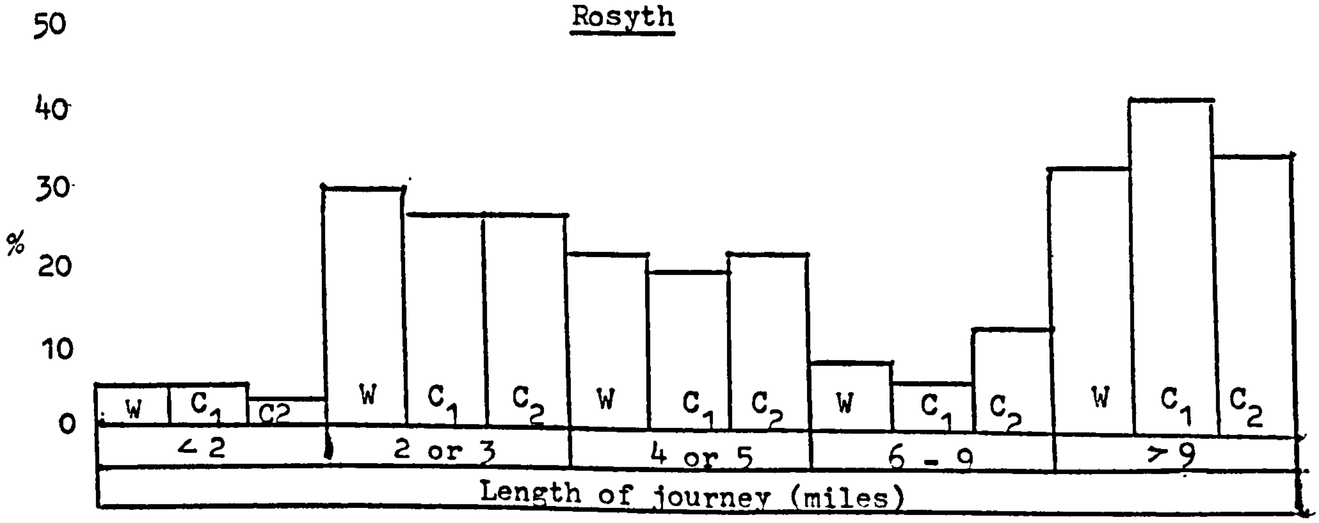
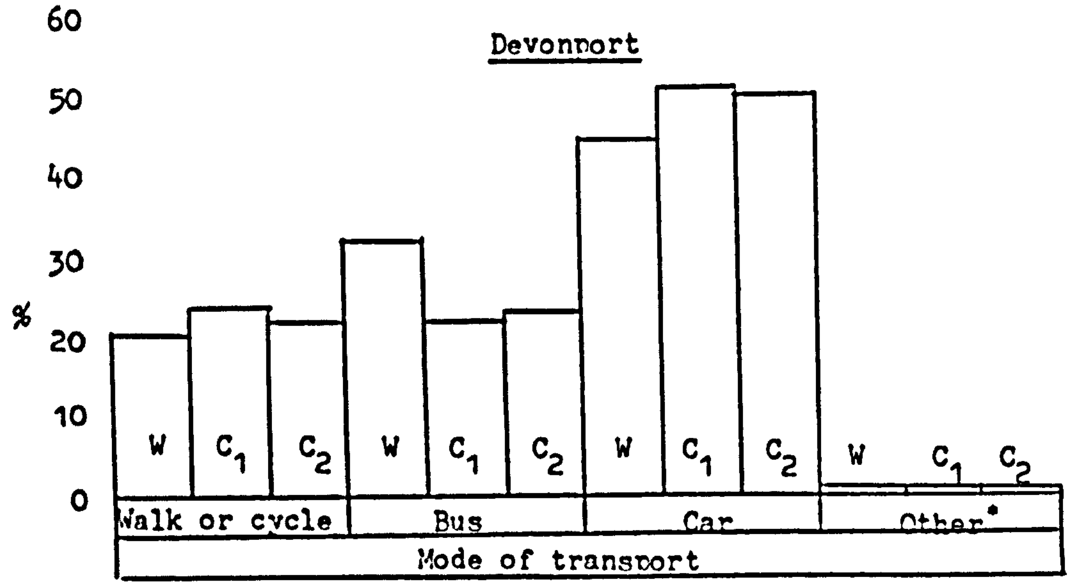
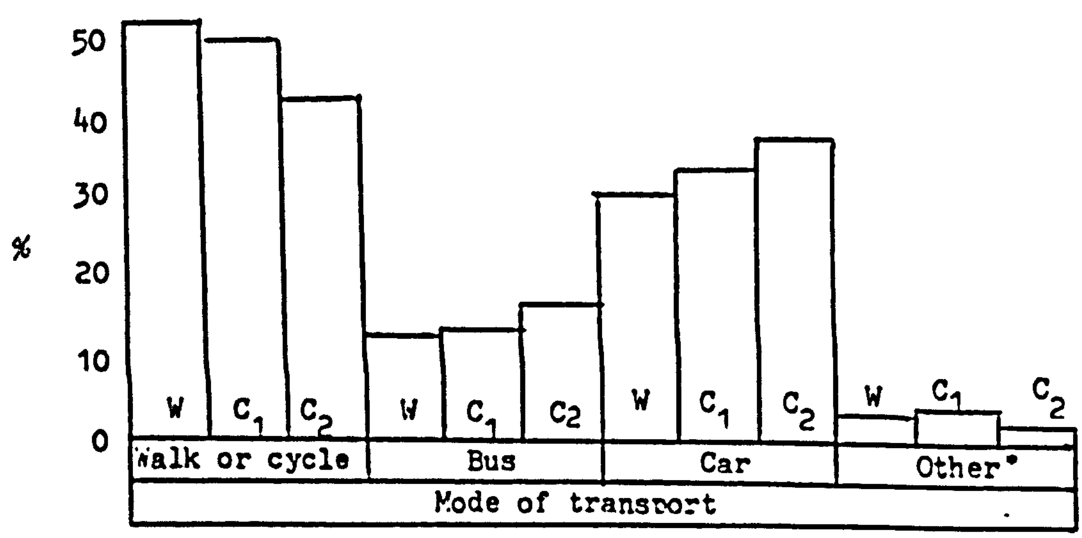


FIGURE A6 Percentage of men in welders and controls in each Dockyard using various modes of transport to work

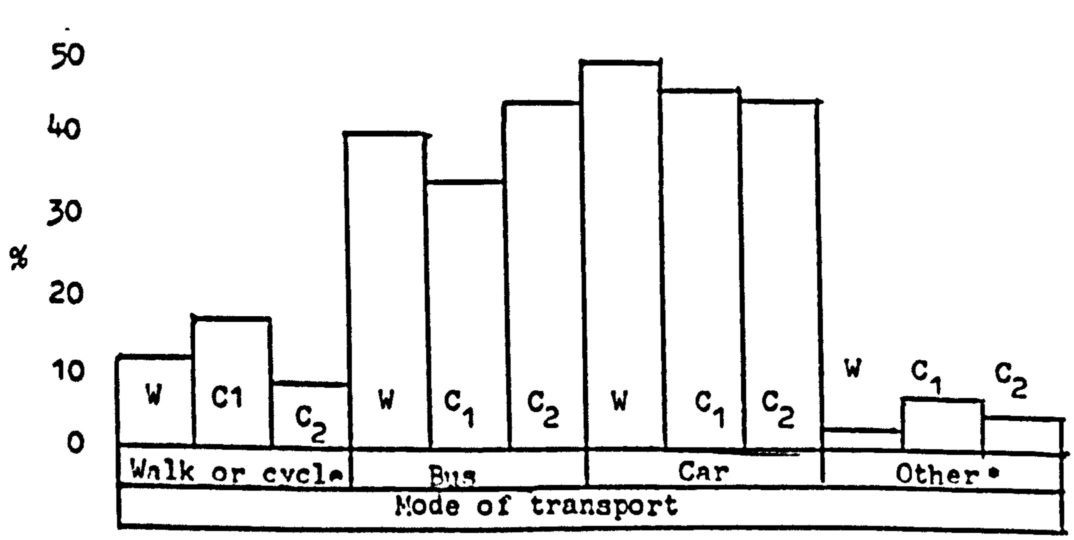
Devonport



Portsmouth



Rosyth



* Mainly train

FIGURE A 7 New spells of absence attributed to all causes (certificated and uncertificated) per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

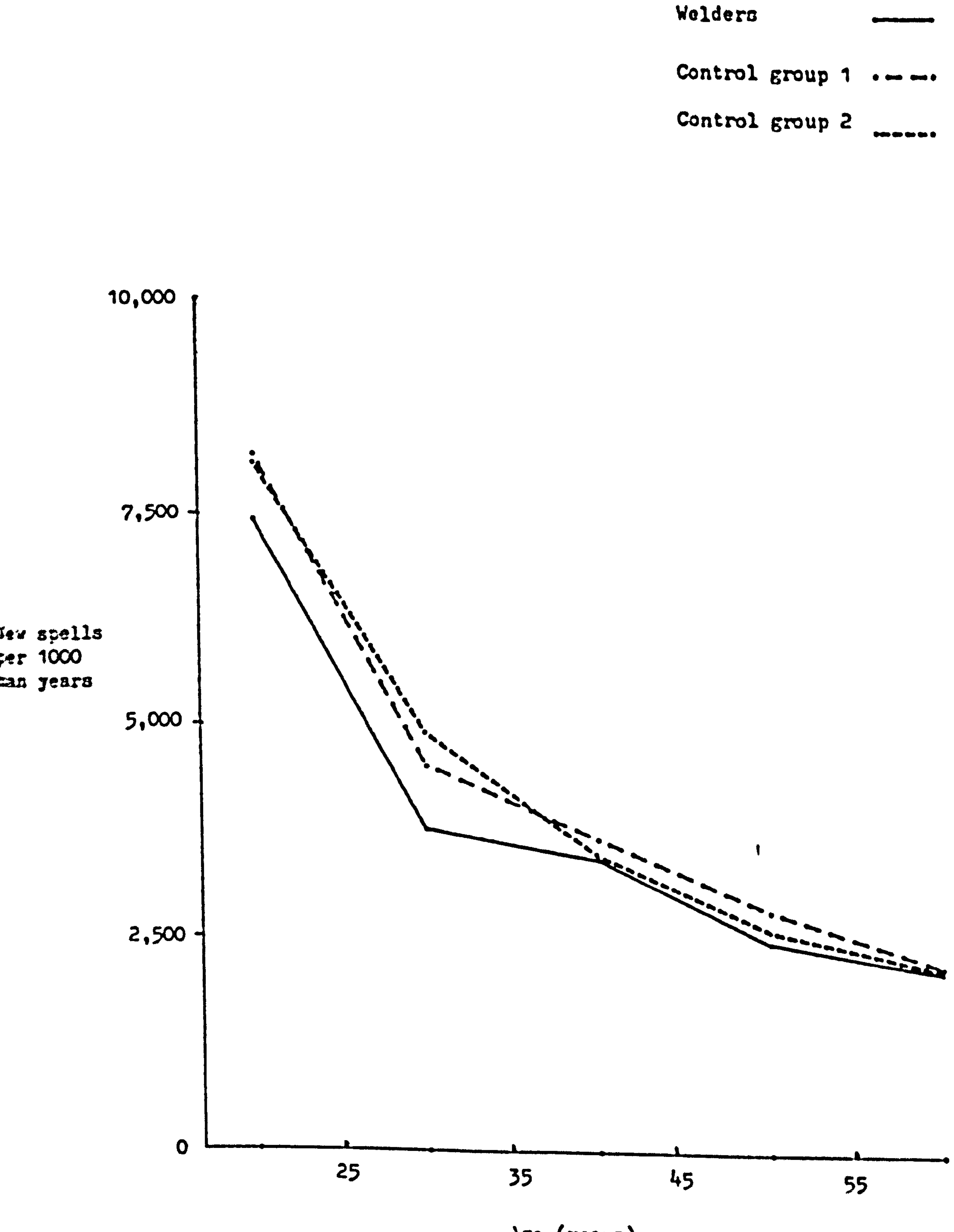
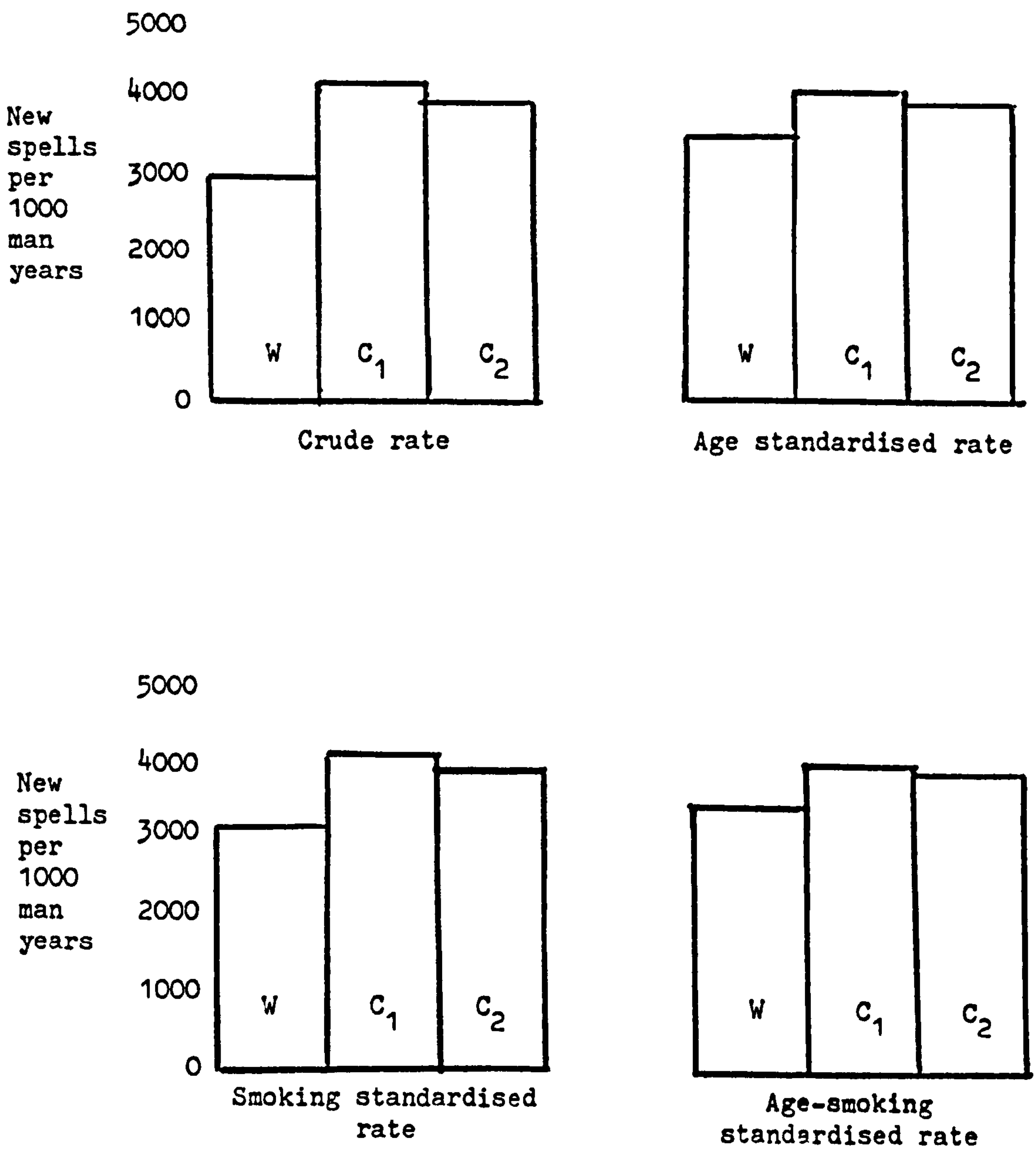
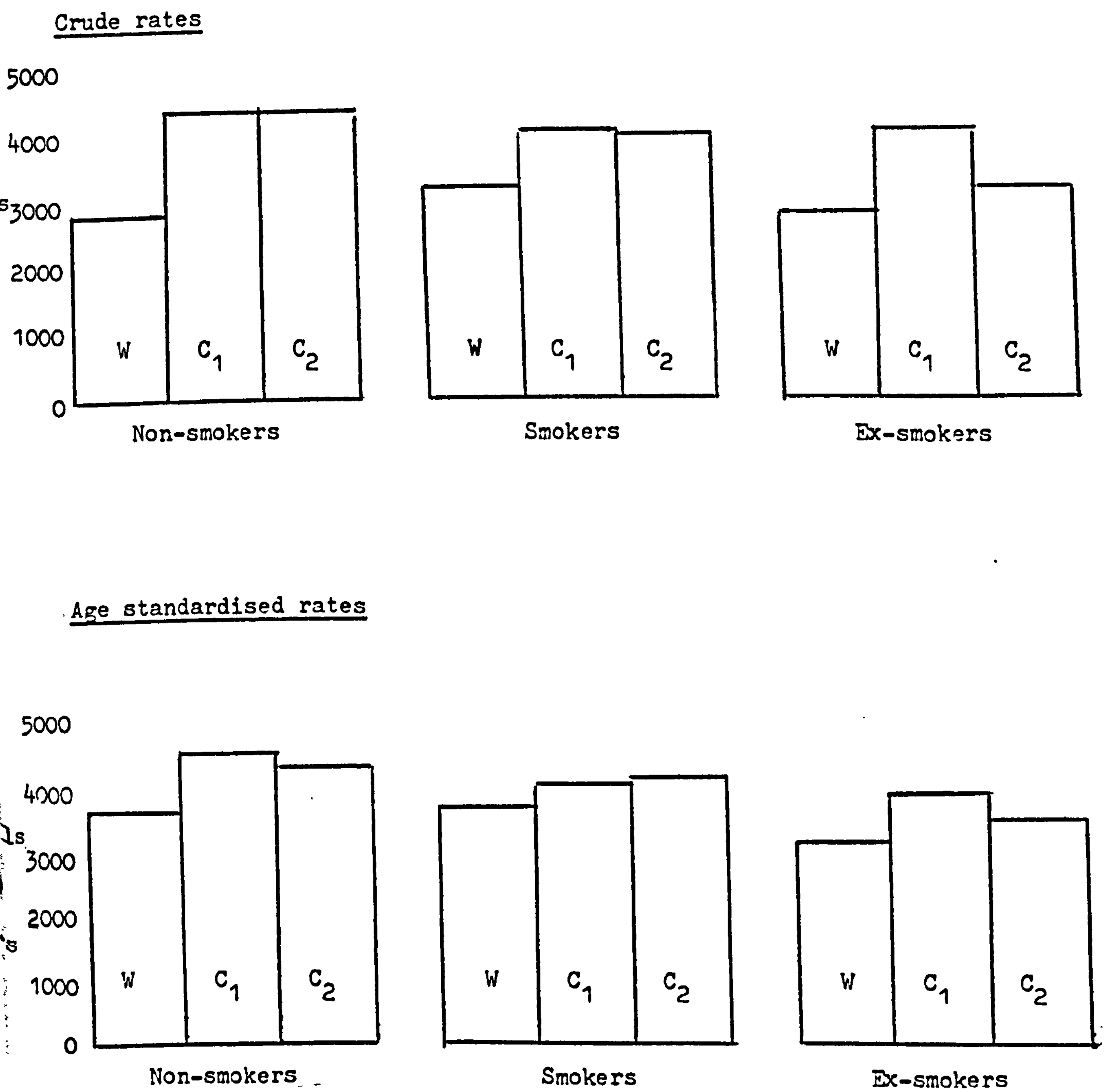


FIGURE A8 Crude and standardised rates of new spells of absence attributed to all causes (certificated and uncertificated) per 1000 man-years in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A9 Crude and age standardised rates of new spells of absence attributed to all causes (certificated and uncertificated) per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A10 Inception rate per 100 persons for absence attributed to all causes (certificated and uncertificated) in welders and controls in Dockyard Combined Population related to age.

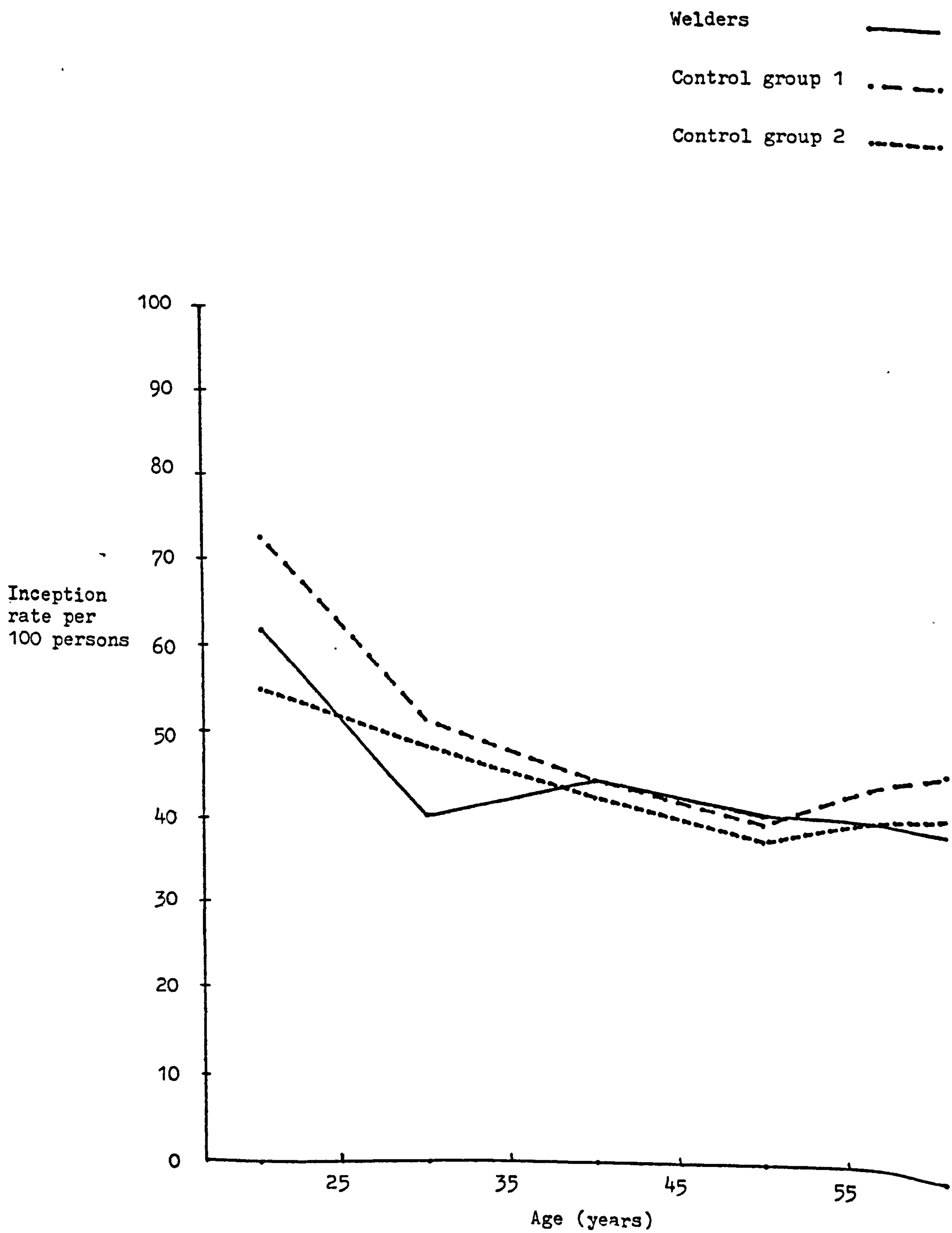


FIGURE A11 Crude and standardised inception rate per 100 persons for absence atrributed to all causes (certificated and uncertificated) in welders and controls in Dockyard Combined Population

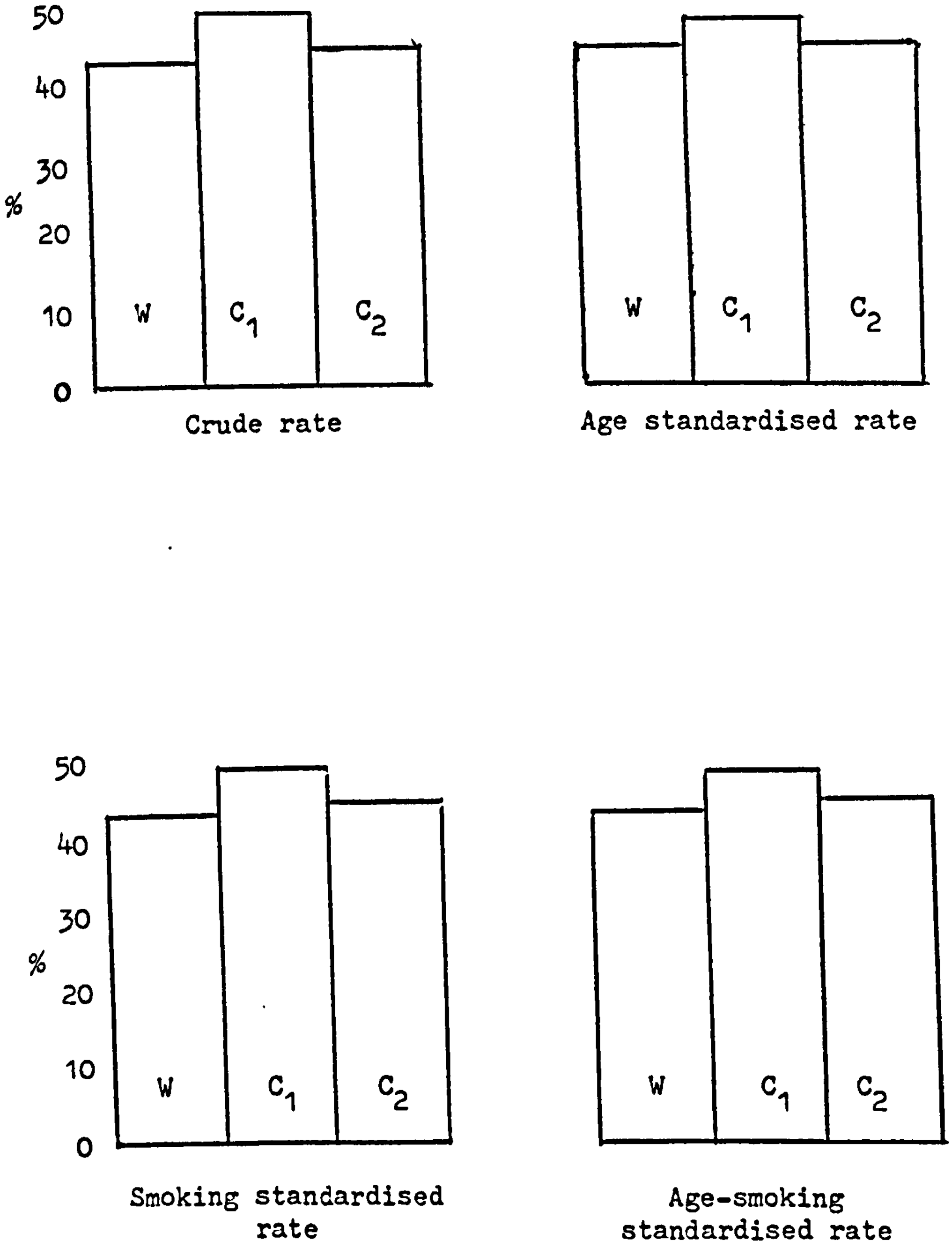
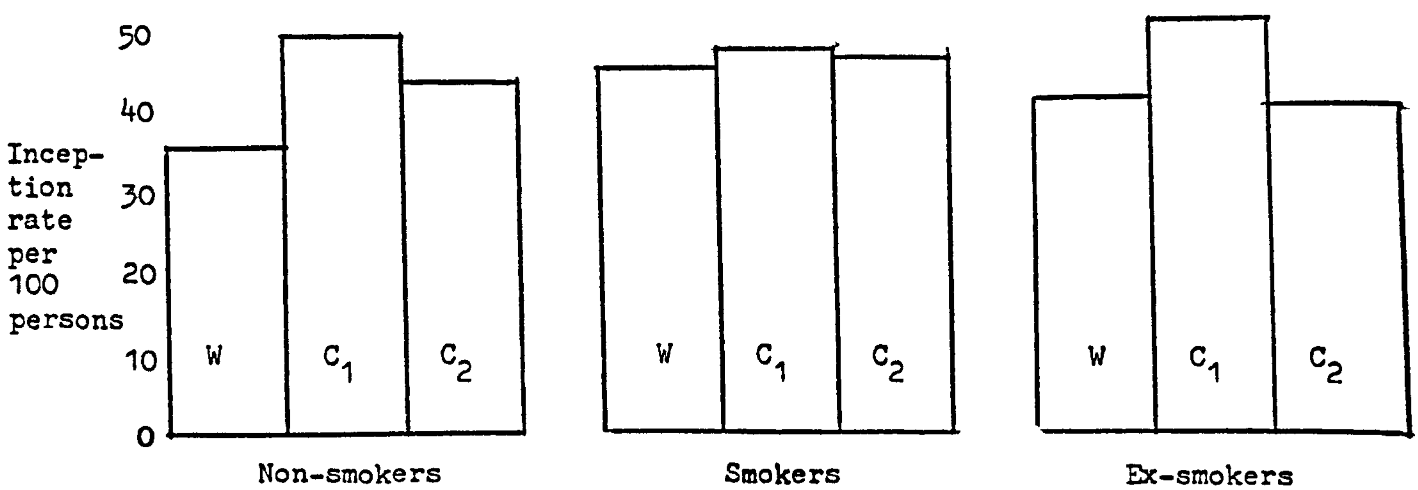
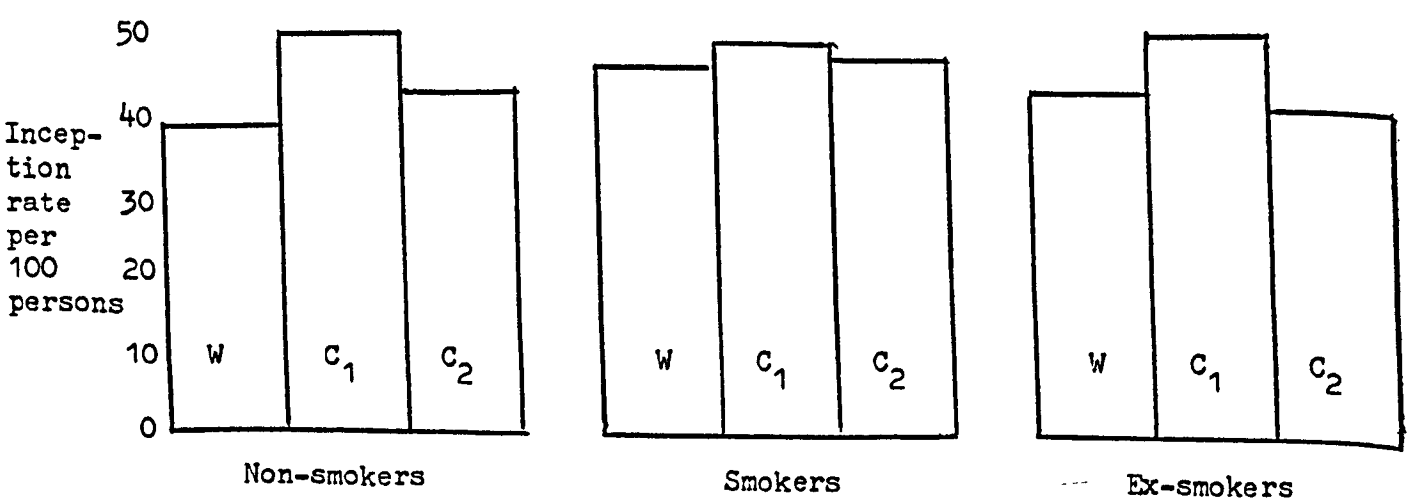


FIGURE A12 Crude and age standardised inception rates per 100 persons for absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude rates



Standardised rates



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 13 Mean annual duration (days) of absence attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population related to age

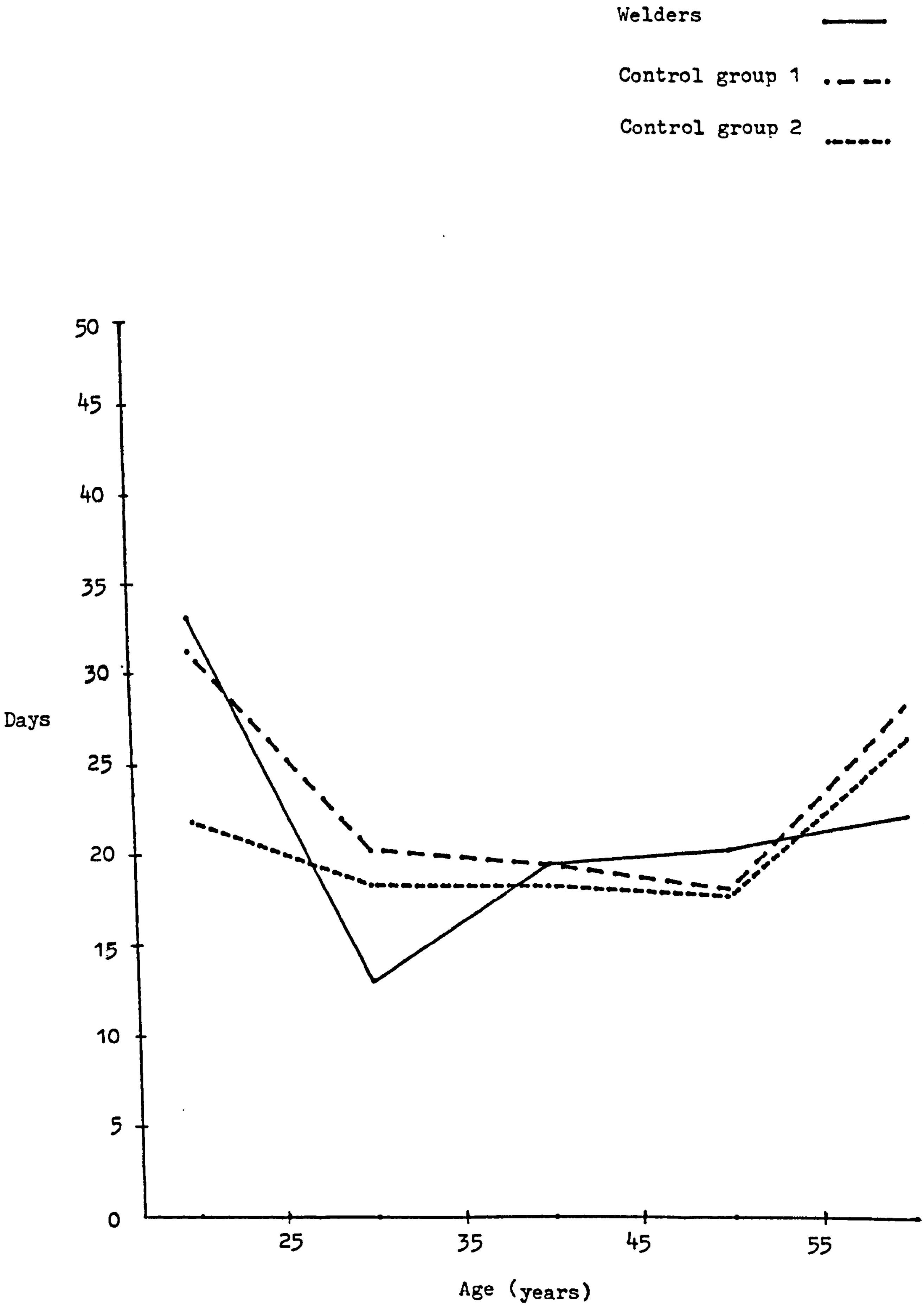
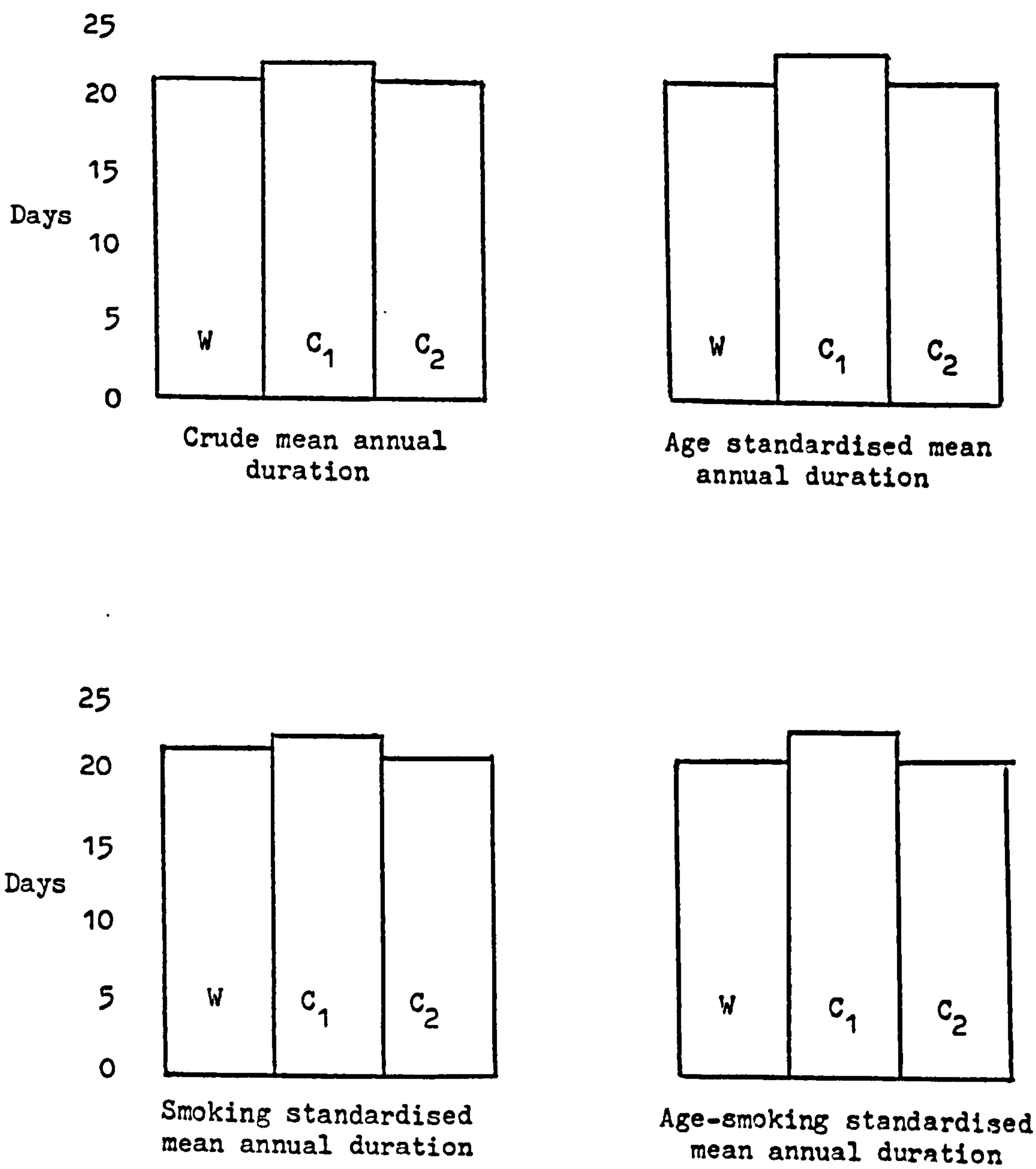


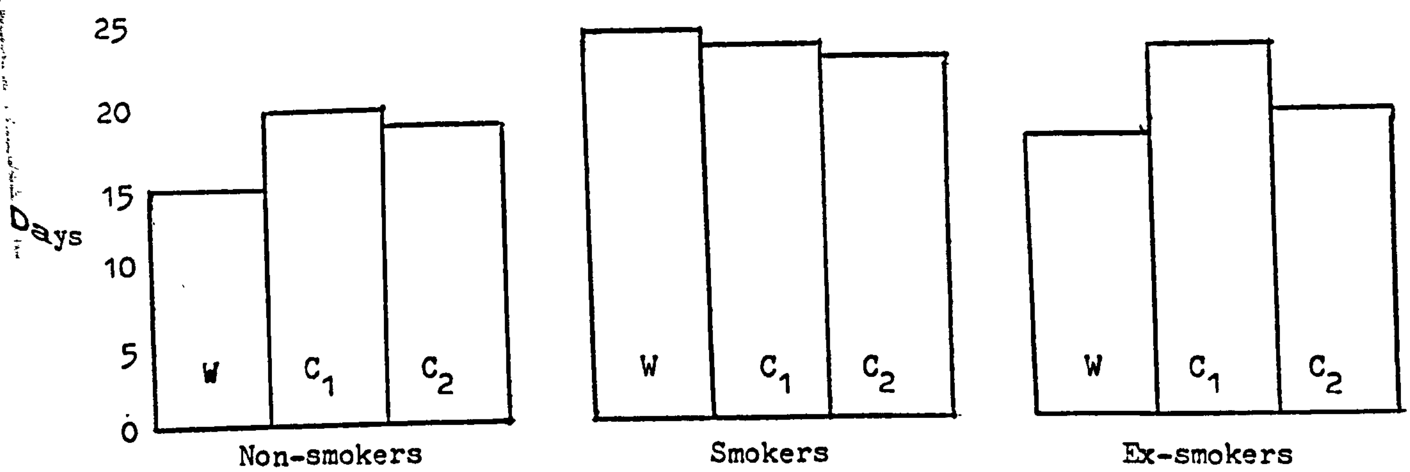
FIGURE A14 Crude and standardised mean annual duration (days) of absence attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population



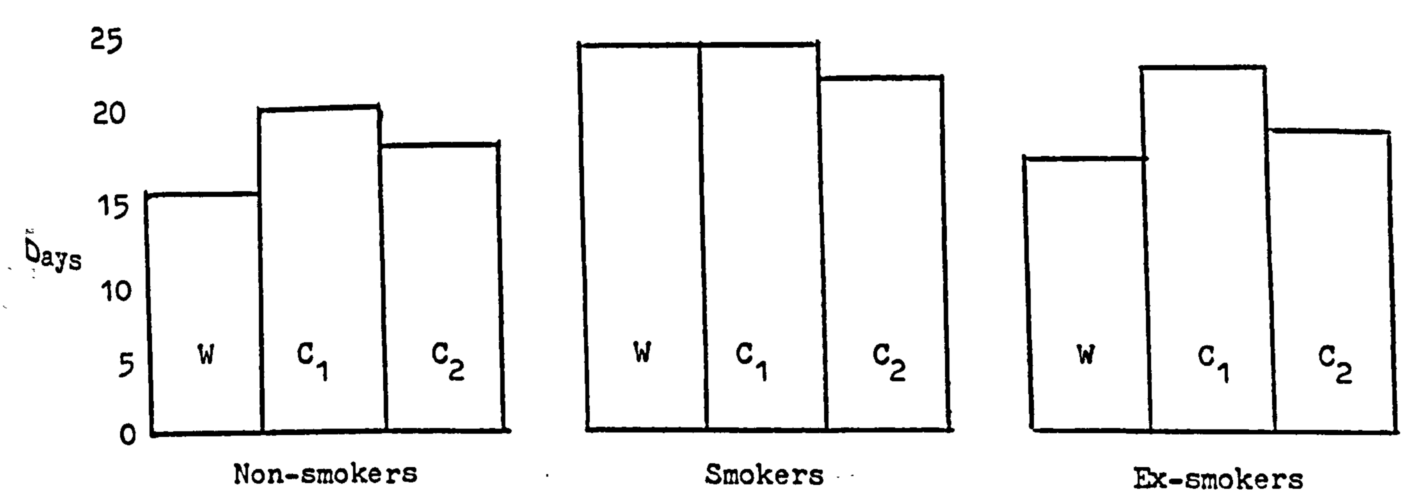
W = Welders C_1 = Control group 1 C_1 = Control group 2

FIGURE A15 Crude and age standardised mean annual duration (days) of absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude rates



Standardised rates



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 16 Mean length of spell (days) of absence attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population related to age

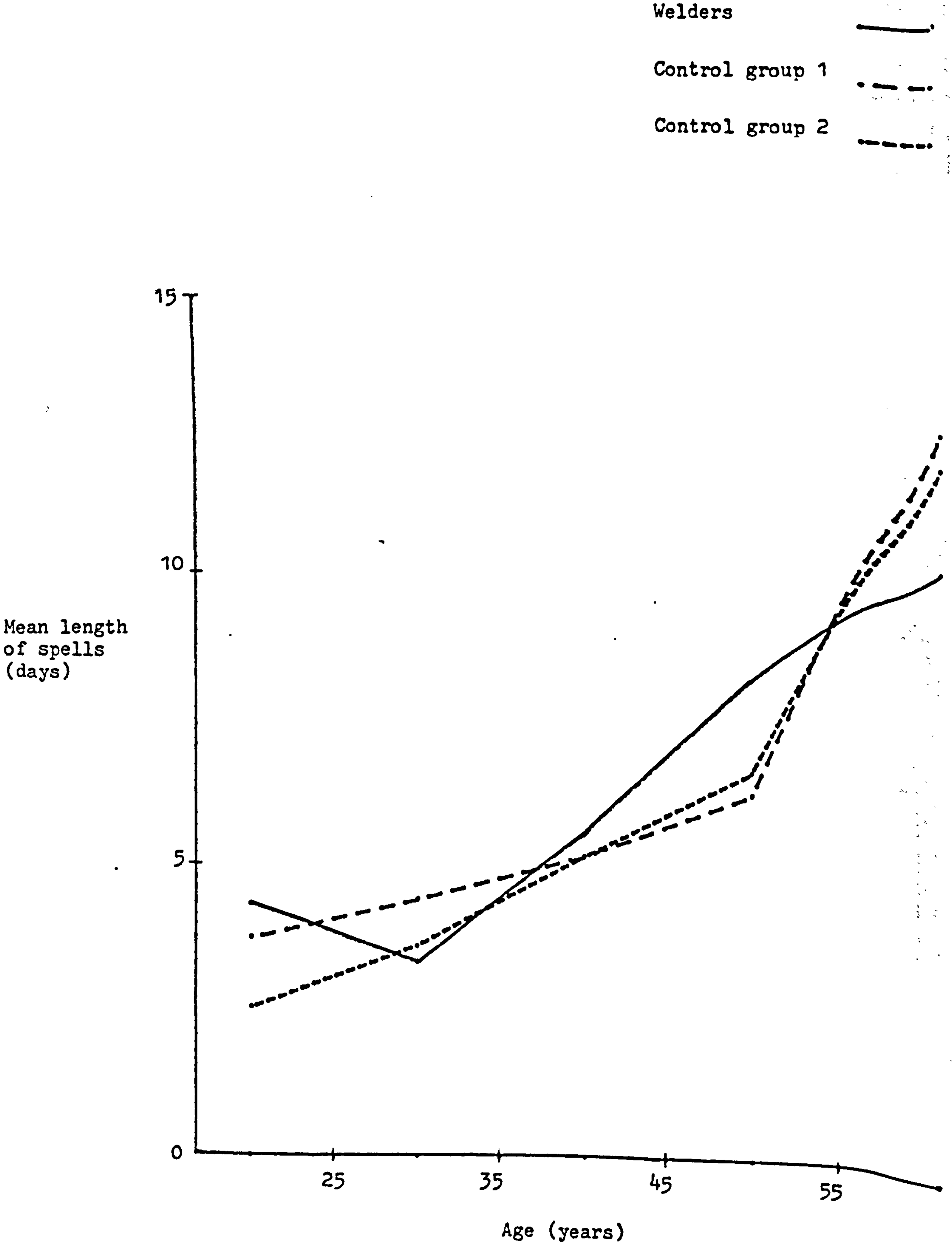
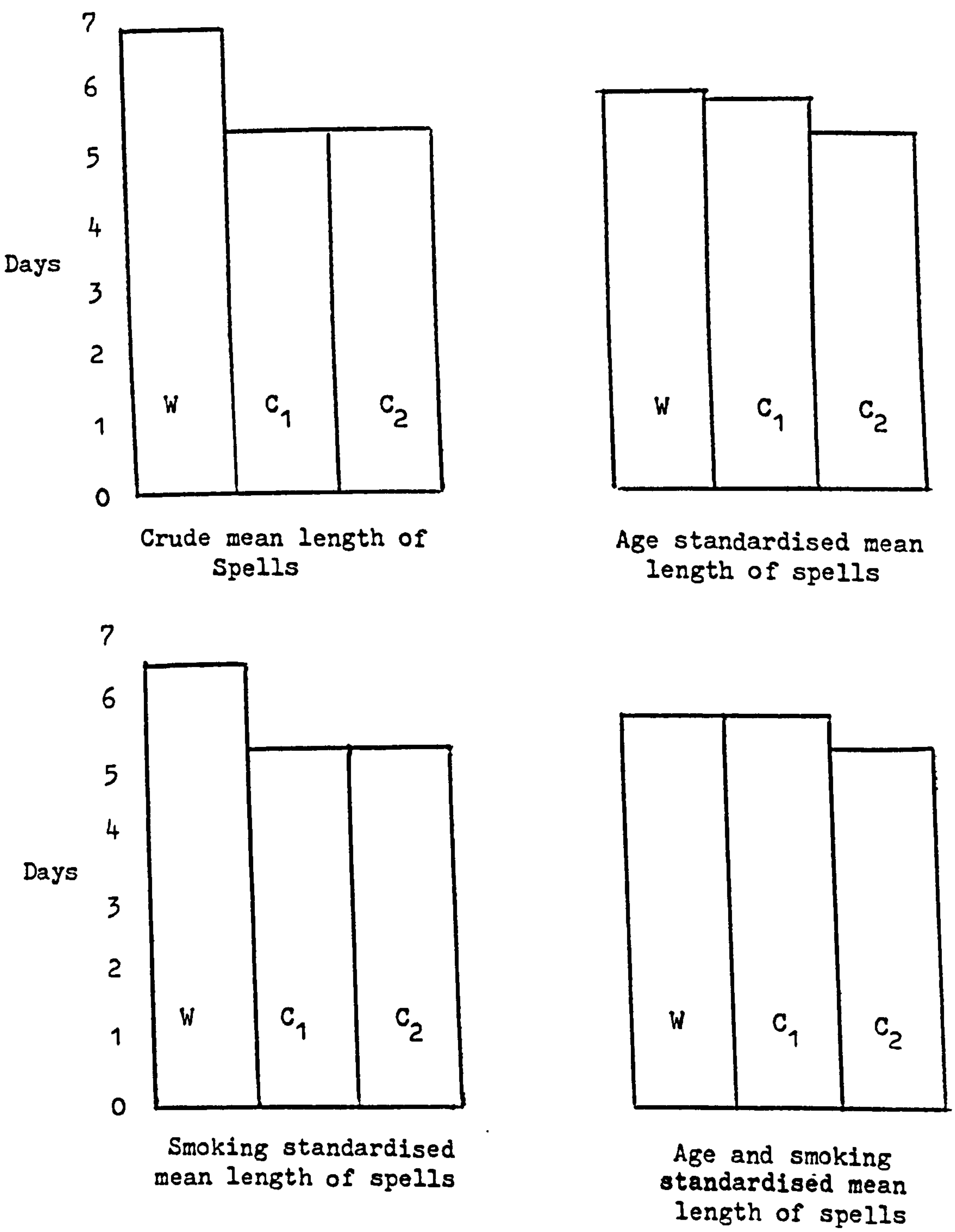
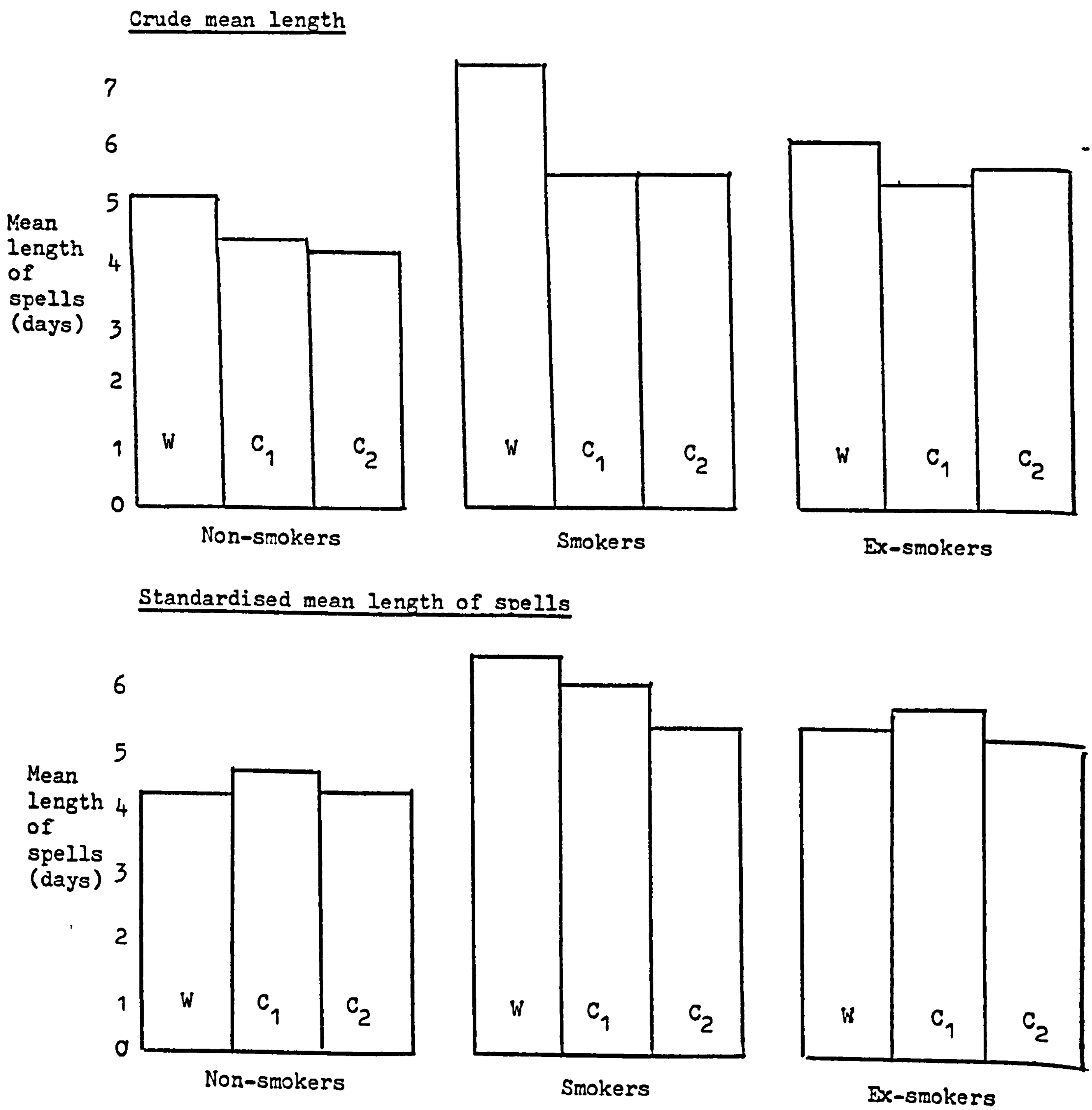


FIGURE A17 Crude and standardised mean length of spell (days) of absence attributed to all causes (certificated and uncertificated) in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 18 Crude and age standardised mean length of spells (days) of absence attributed to all causes (certificated and uncertificated) in non-smokers, smokers and ex-smokers in welders and control group in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A19 New spells of absence attributed to all respiratory diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

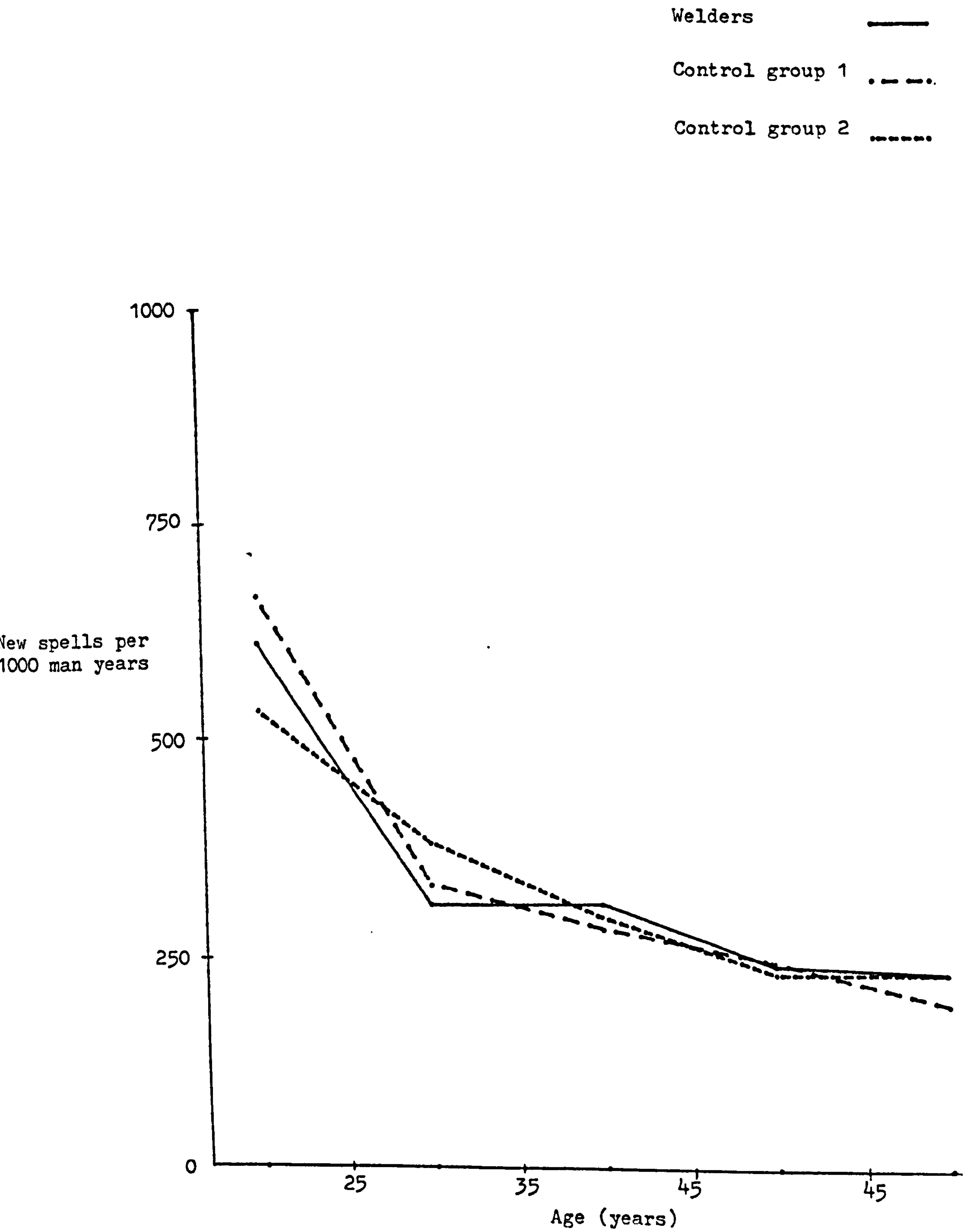
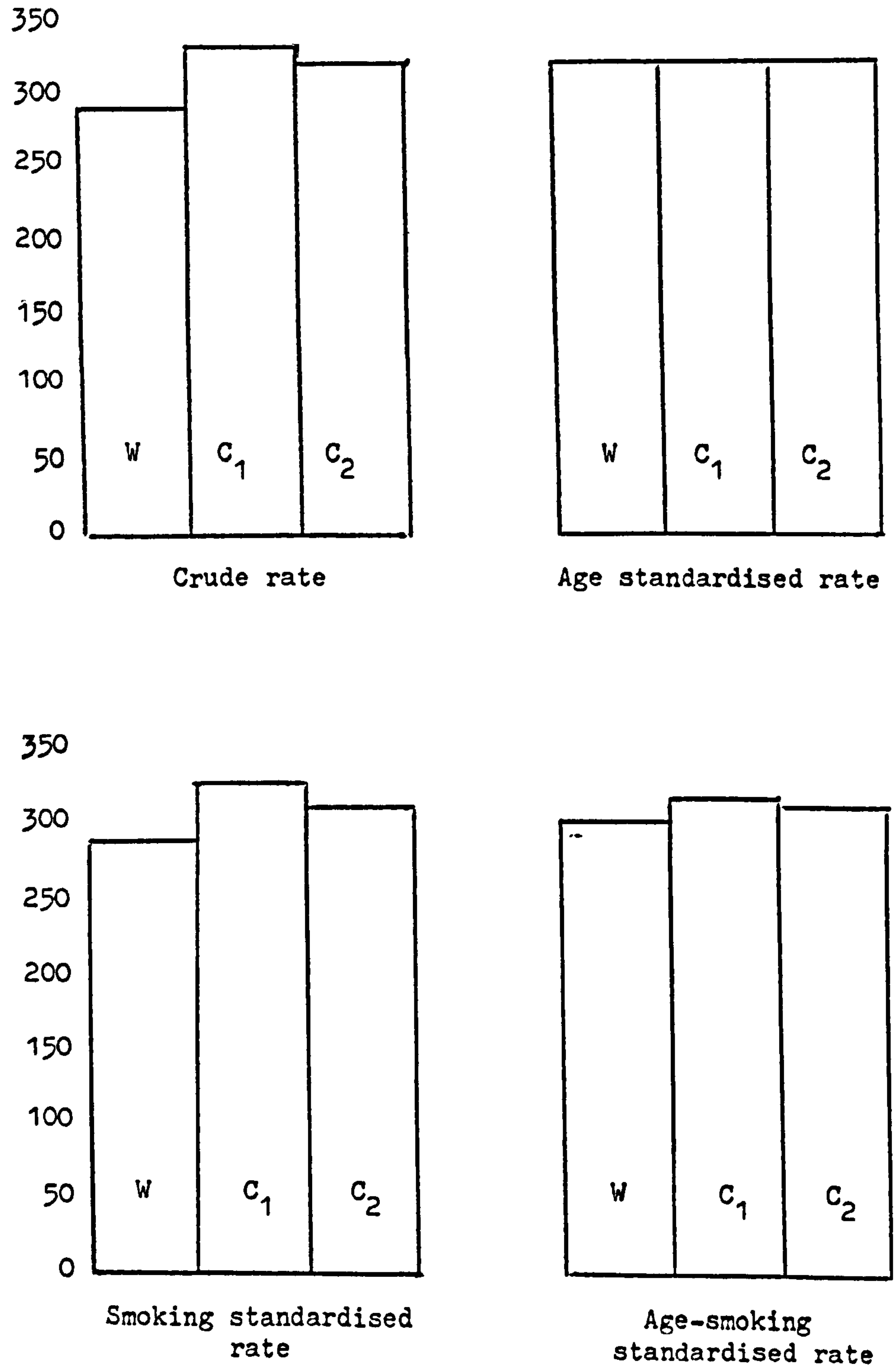


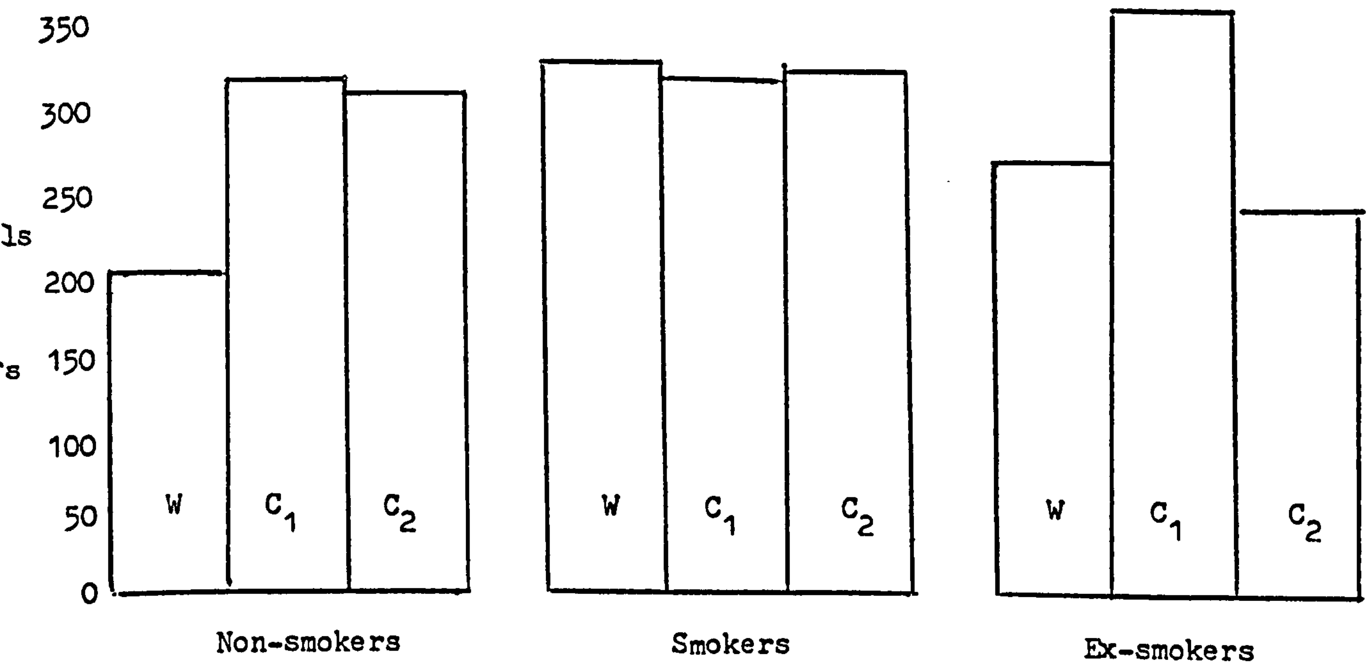
FIGURE A 20 Crude and standardised rates of new spells of absence attributed to all respiratory diseases per 1000 man-years in welders and control groups in Dockyard Combined Population



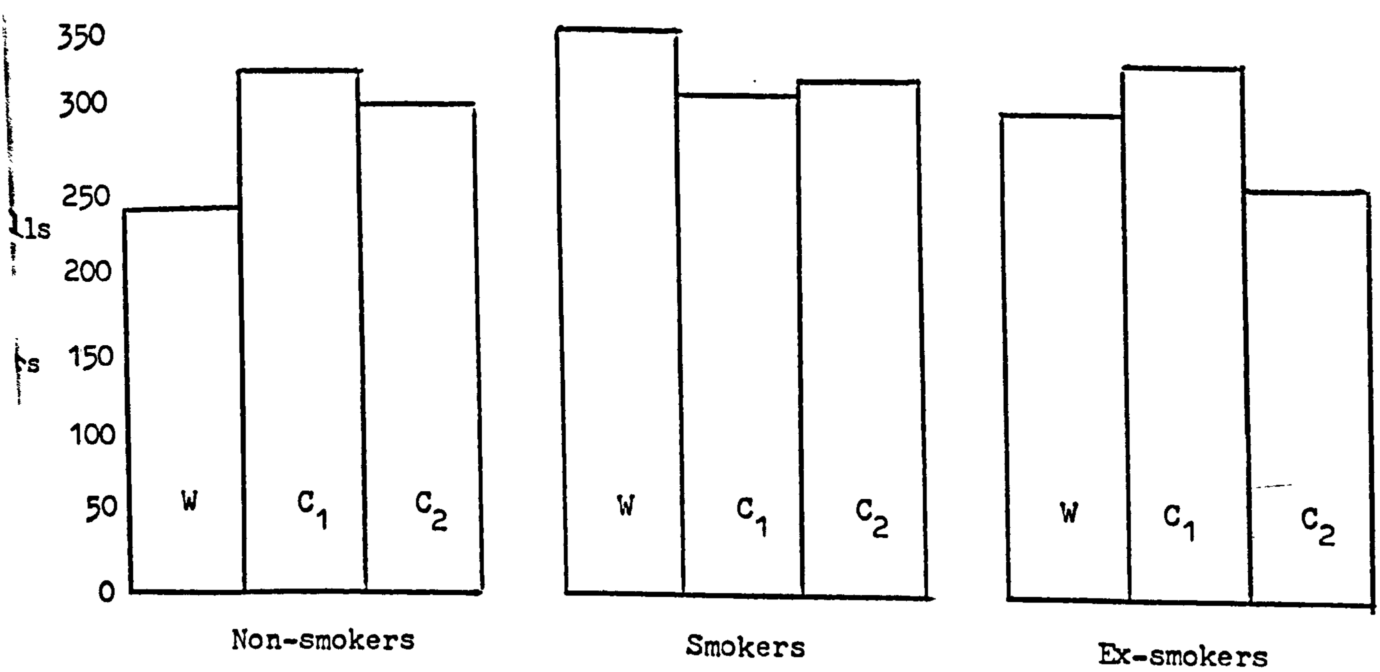
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 21 Crude and age standardised rates of new spells of absence attributed to all respiratory diseases per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude rates



Age standardised rates



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 22 Inception rate per 100 persons for absence attributed to all respiratory diseases in welders and controls in Dockyard Combined Population related to age.

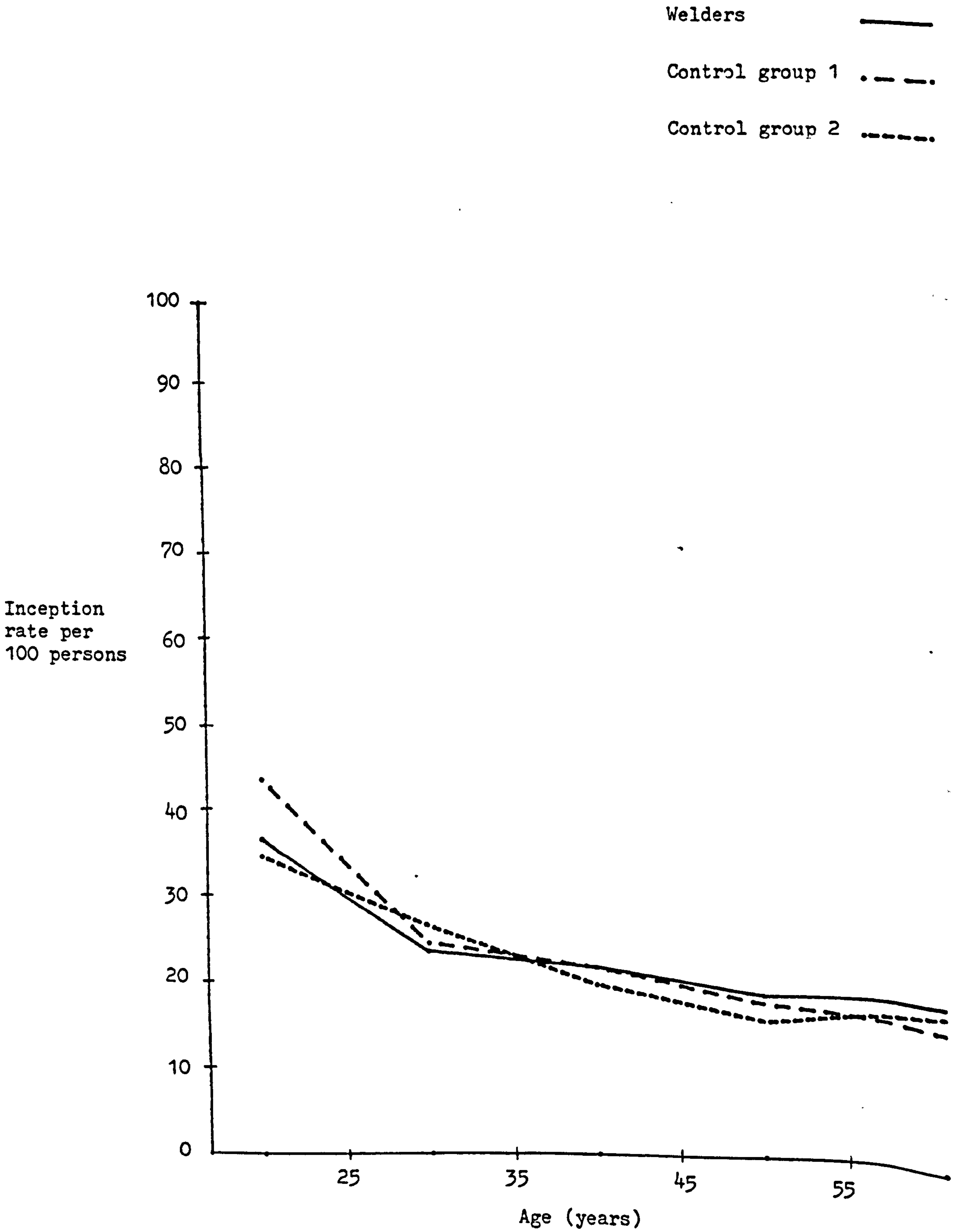
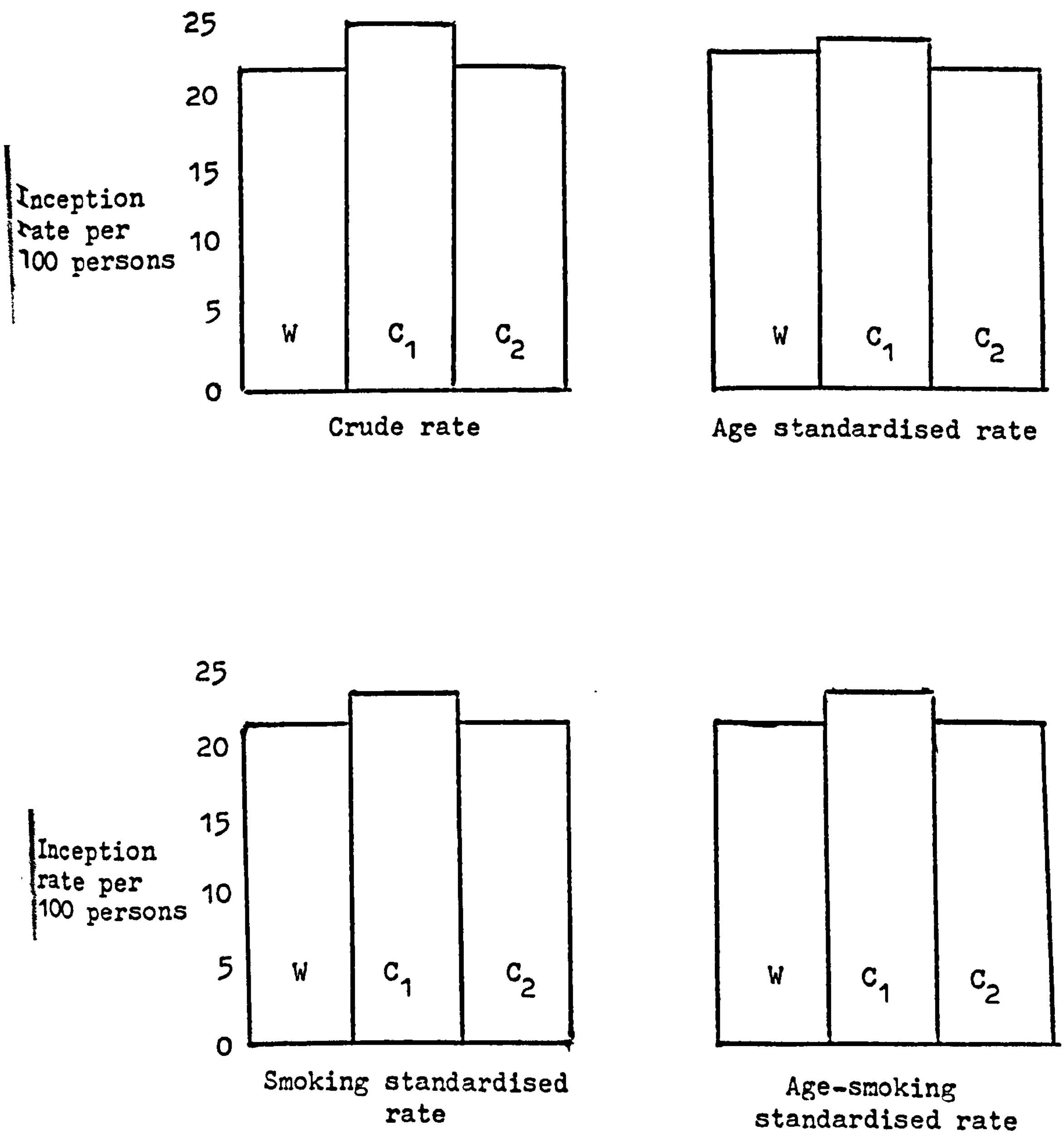


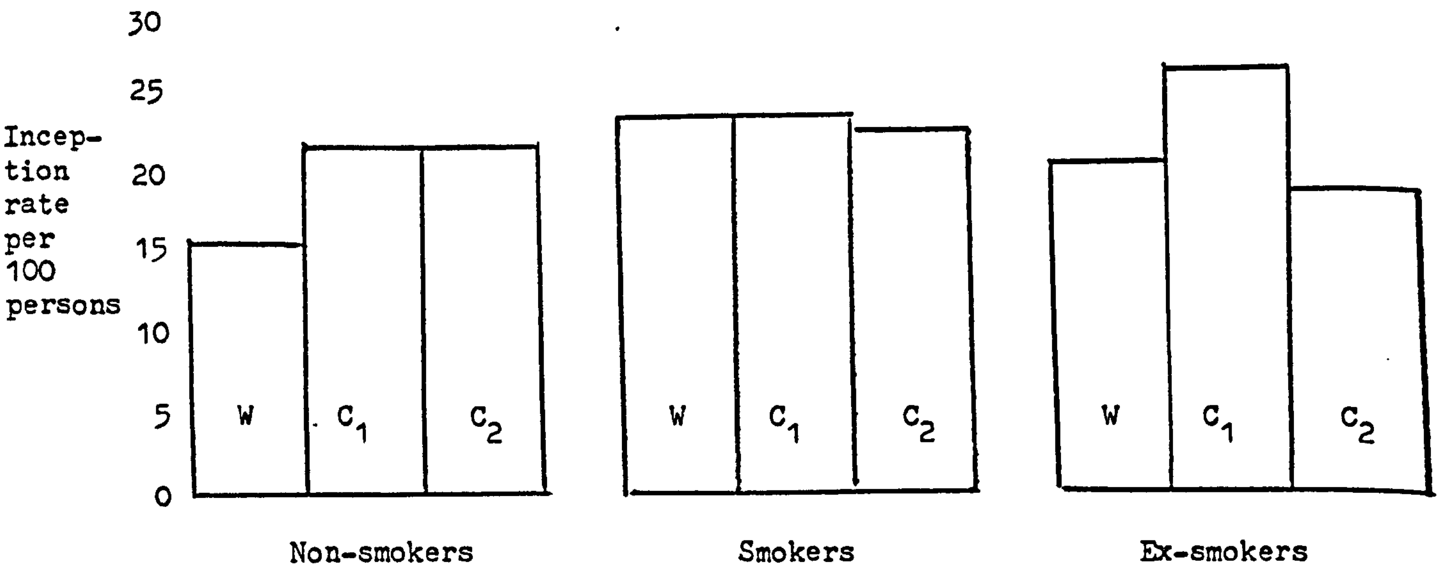
FIGURE A 23 Crude and standardised inception rate per 100 persons for absence attributed to all respiratory diseases in welders and controls in Dockyard Combined Population



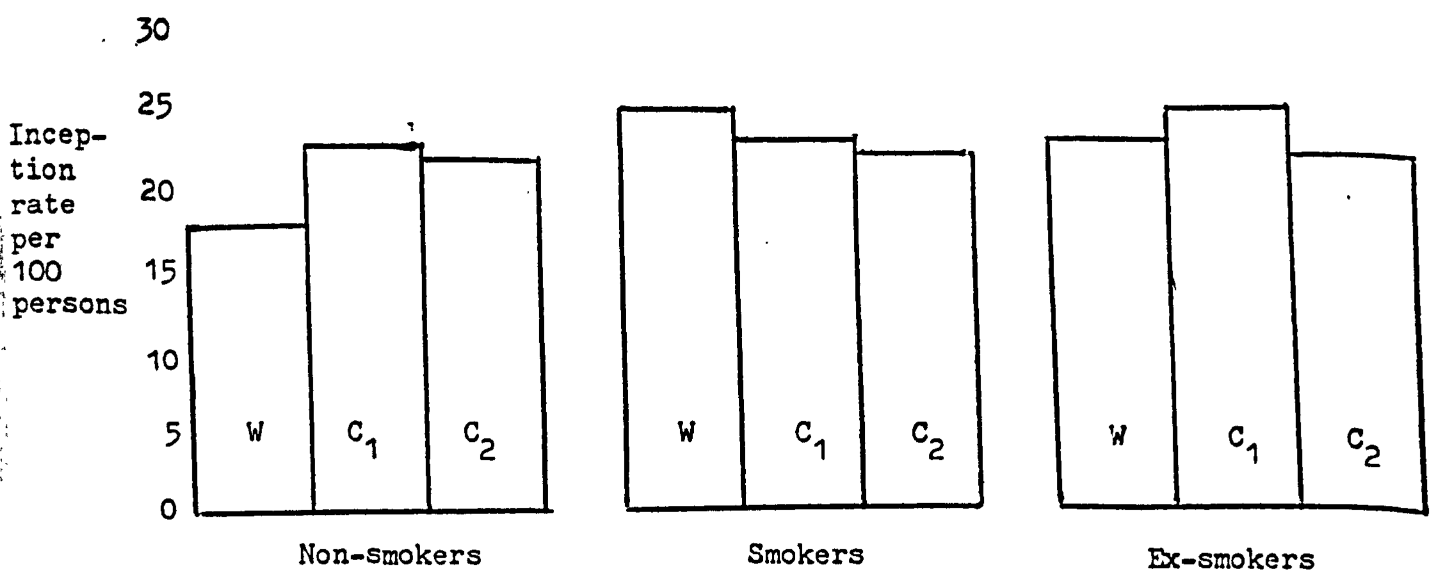
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 24 Crude and age standardised inception rates per 100 persons for absence attributed to all respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude rates



Age standardised rate



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 25 Mean annual duration (days) of absence attributed to all respiratory diseases in welders and control groups in Dockyard Combined Population related to age

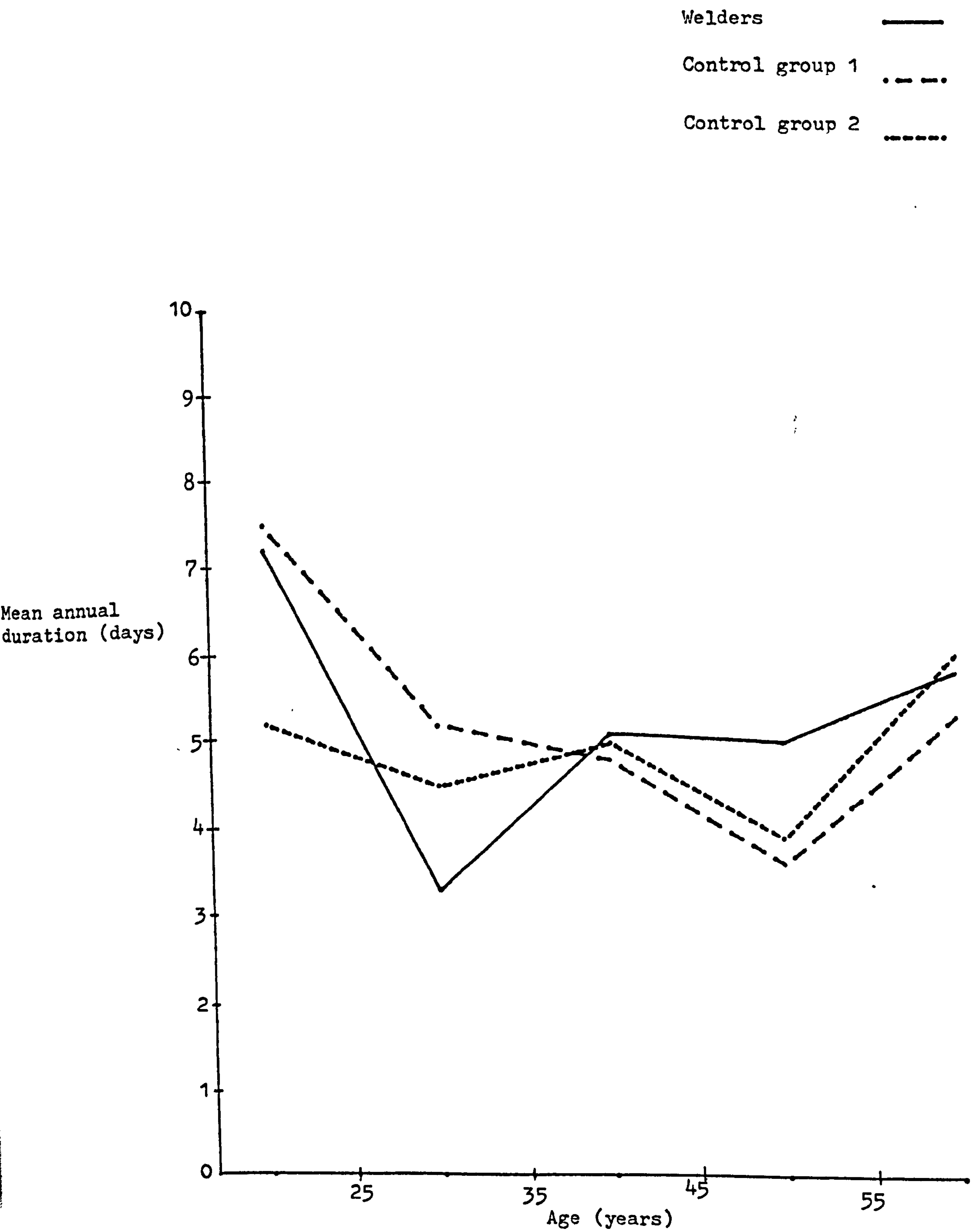
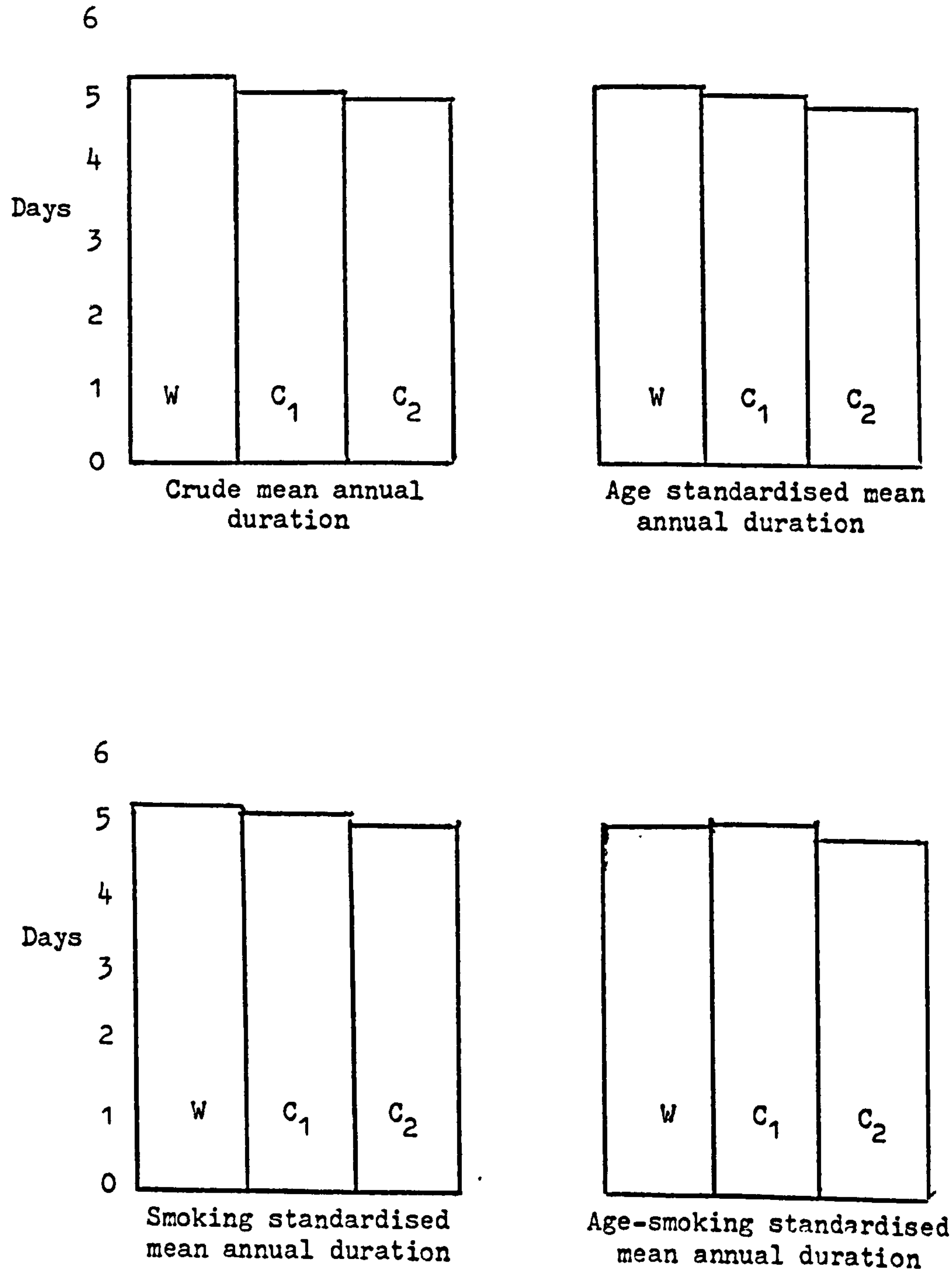


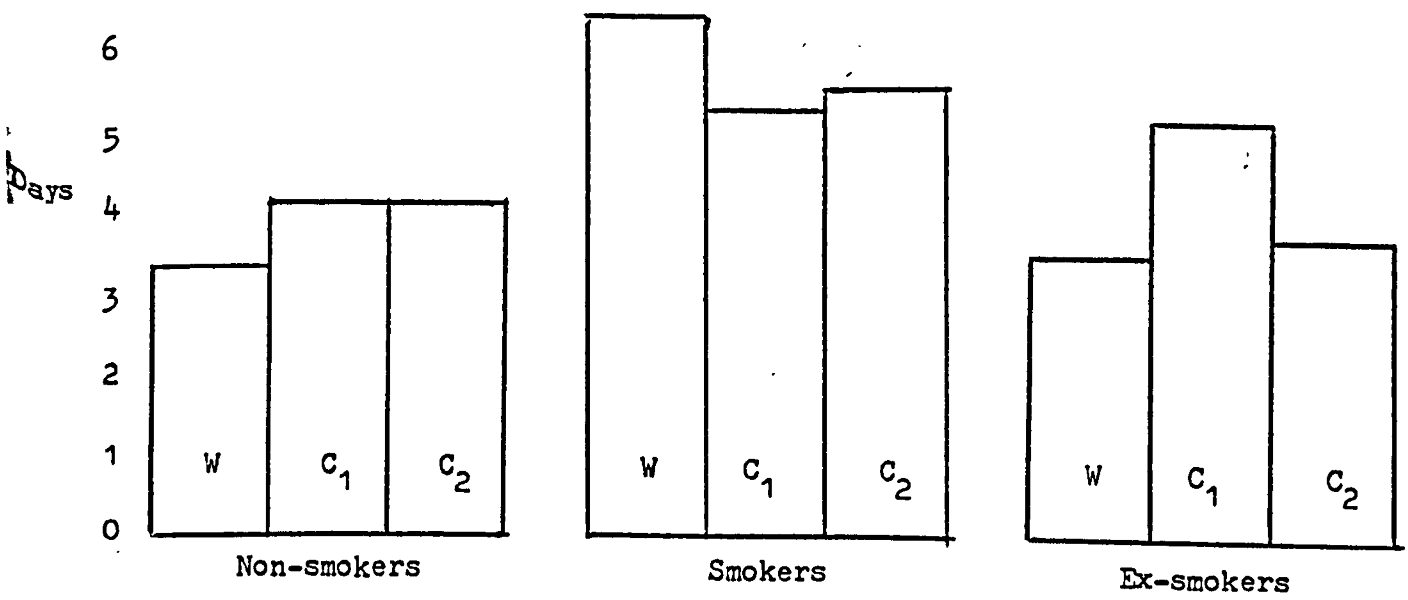
FIGURE A26 Crude and standardised mean annual duration (days) of absence attributed to all respiratory diseases in welders and control groups in Dockyard Combined Population



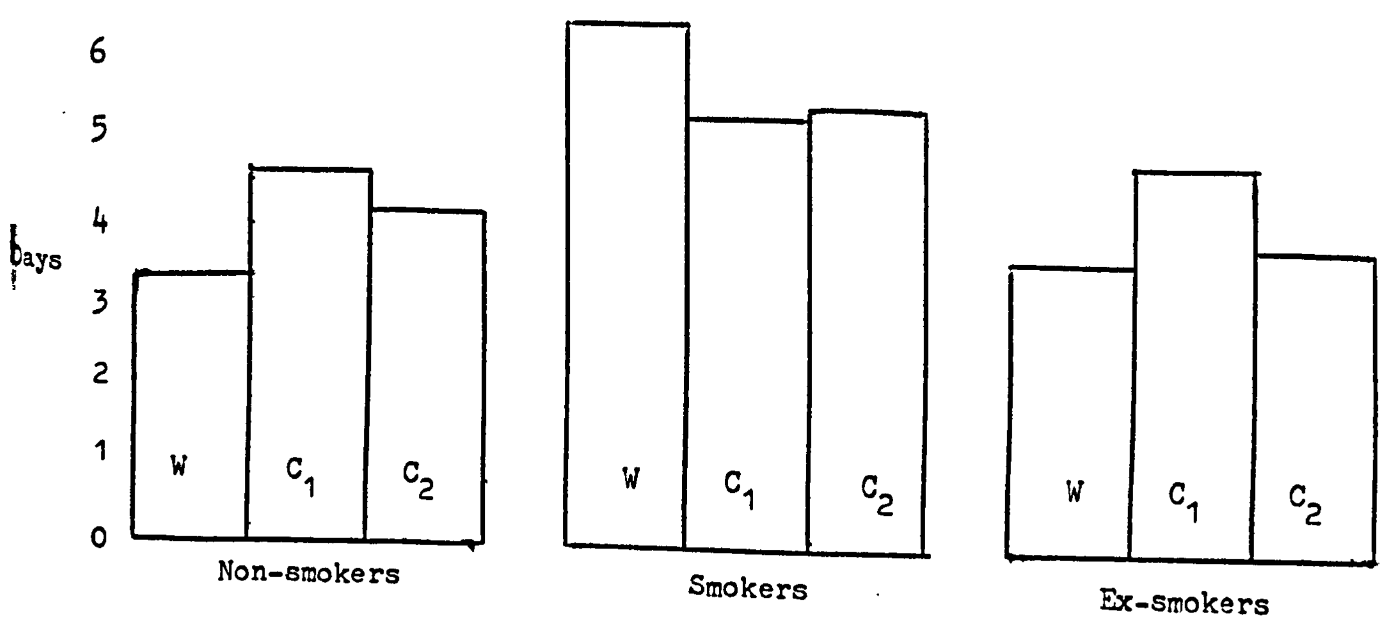
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 27 Crude and age standardised mean annual duration (days) of absence attributed to all respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude mean annual duration



Age standardised mean annual duration



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 28 Mean length of spell (days) of absence attributed to all respiratory diseases in welders and control groups in Dockyard Combined Population related to age

Welders

Control group 1

Control group 2

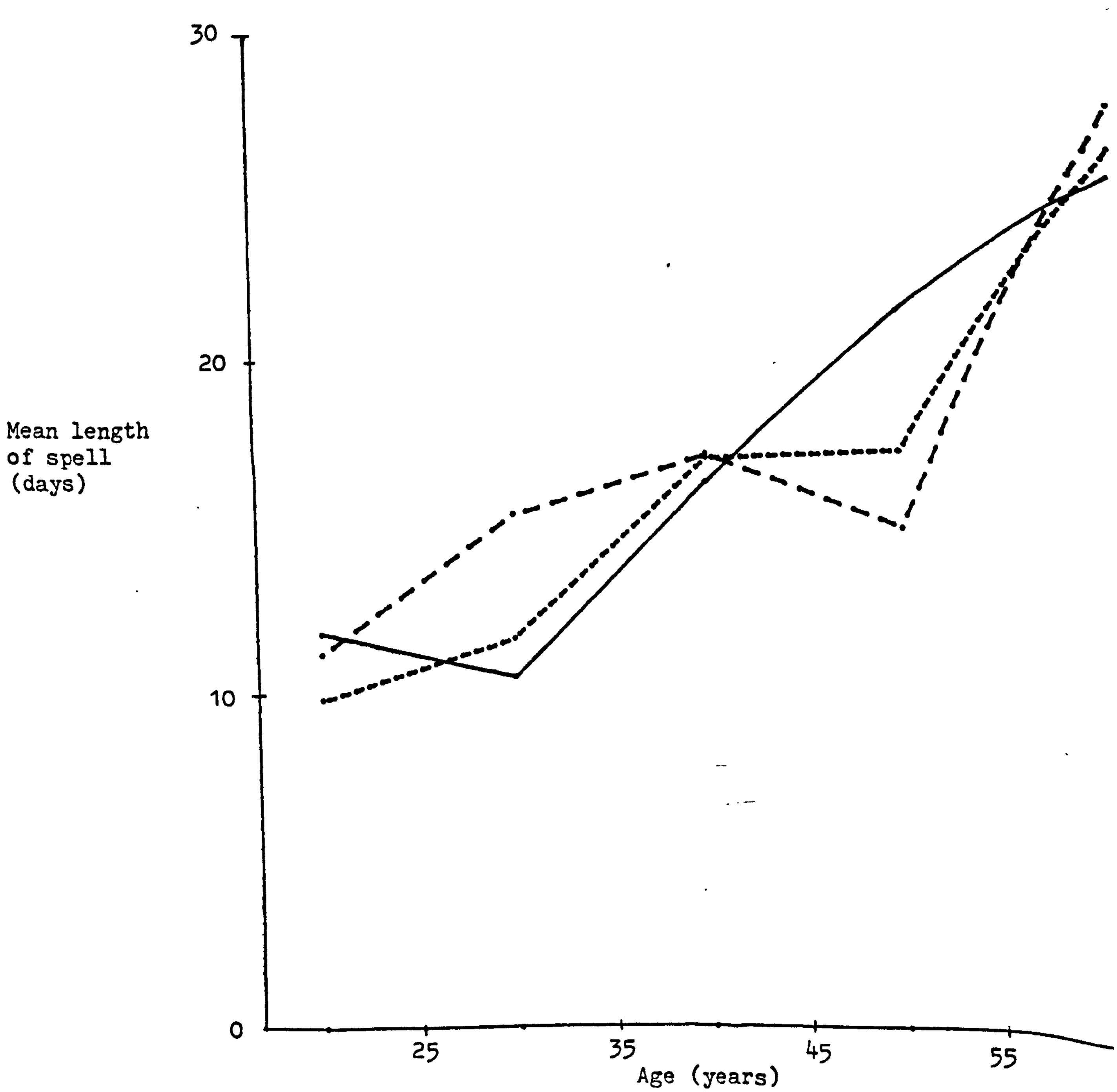
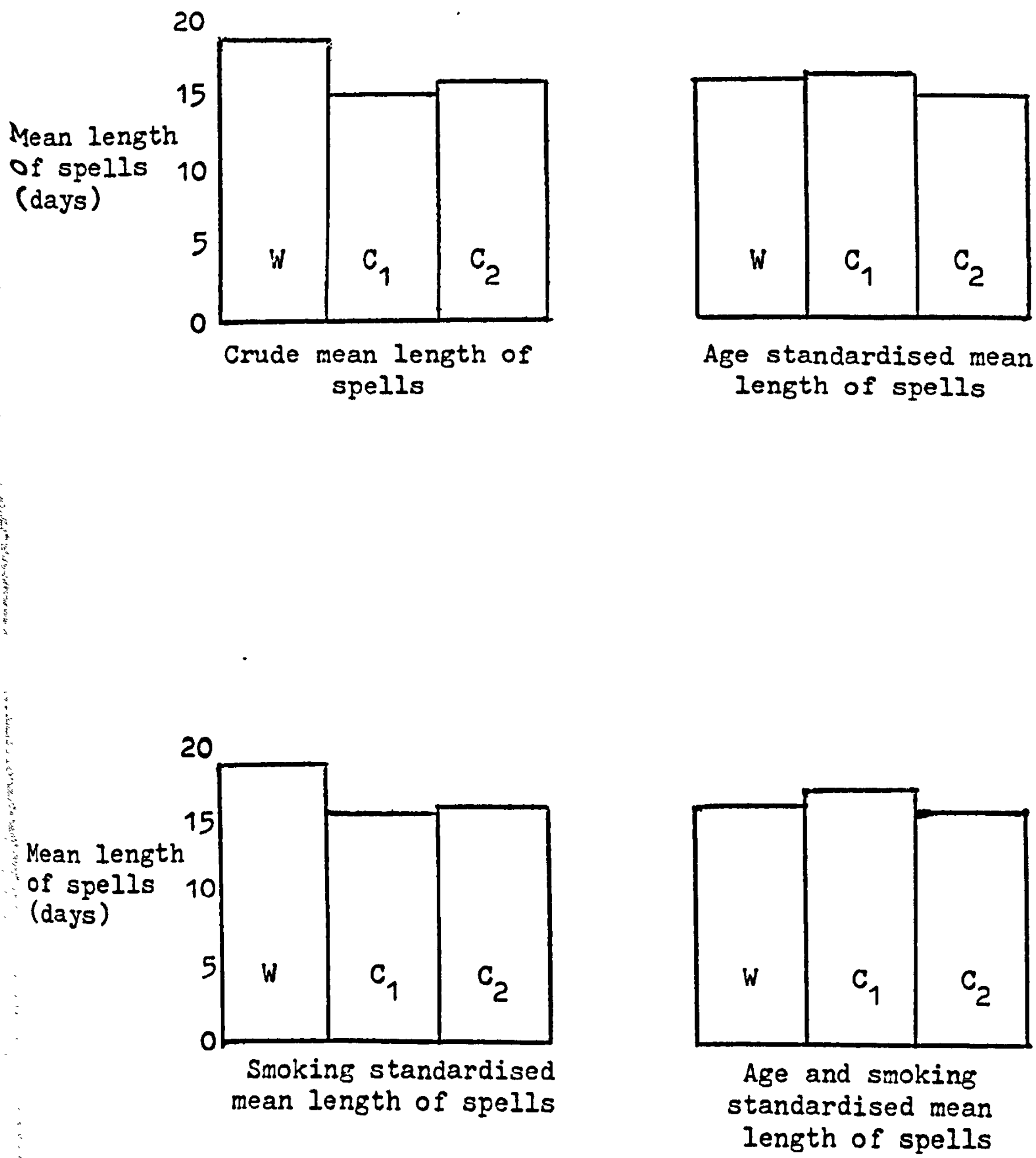


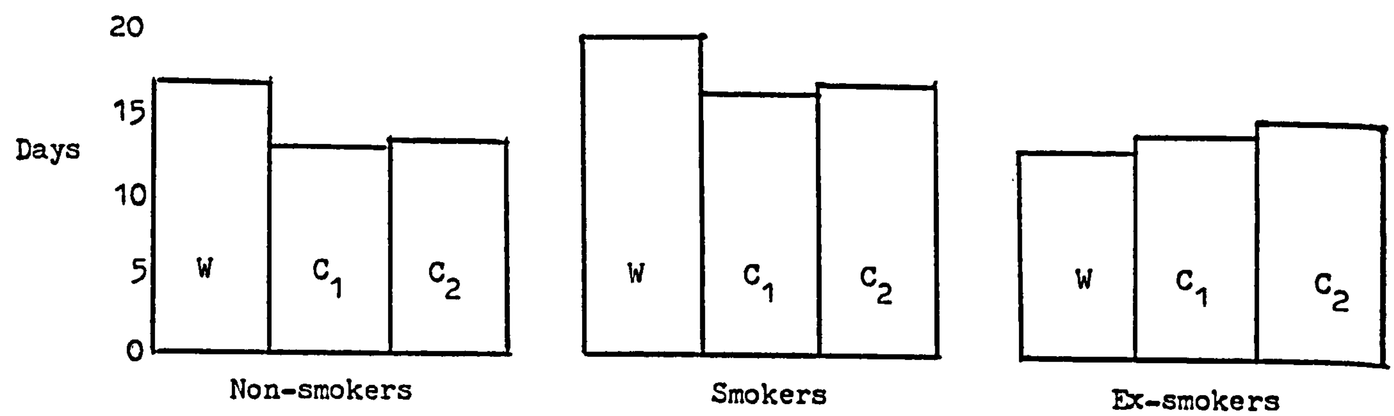
FIGURE A 29 Crude and standardised mean length of spell (days) of absence attributed to all respiratory diseases in welders and control groups in Dockyard Combined Population



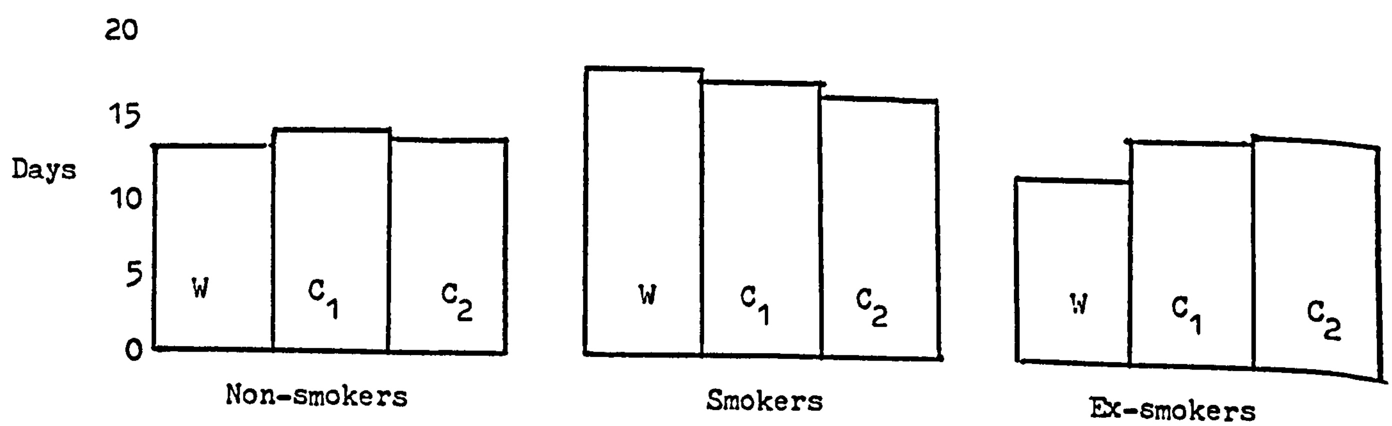
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 30 Crude and standardised mean length of spells (days) of absence attributed to all respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude mean length of spell



Age standardised mean length of spell



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 31 New spells of absence attributed to upper respiratory tract diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

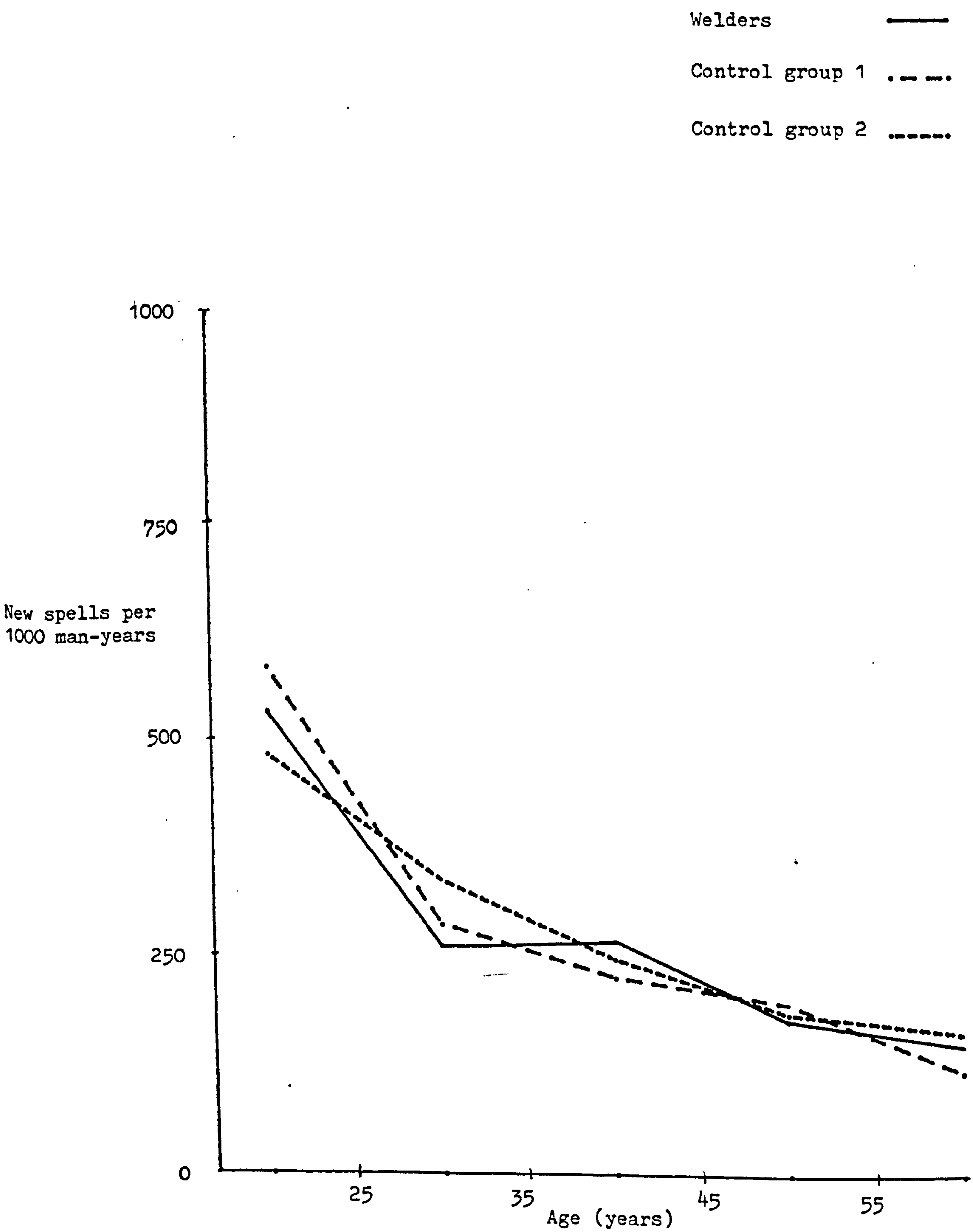
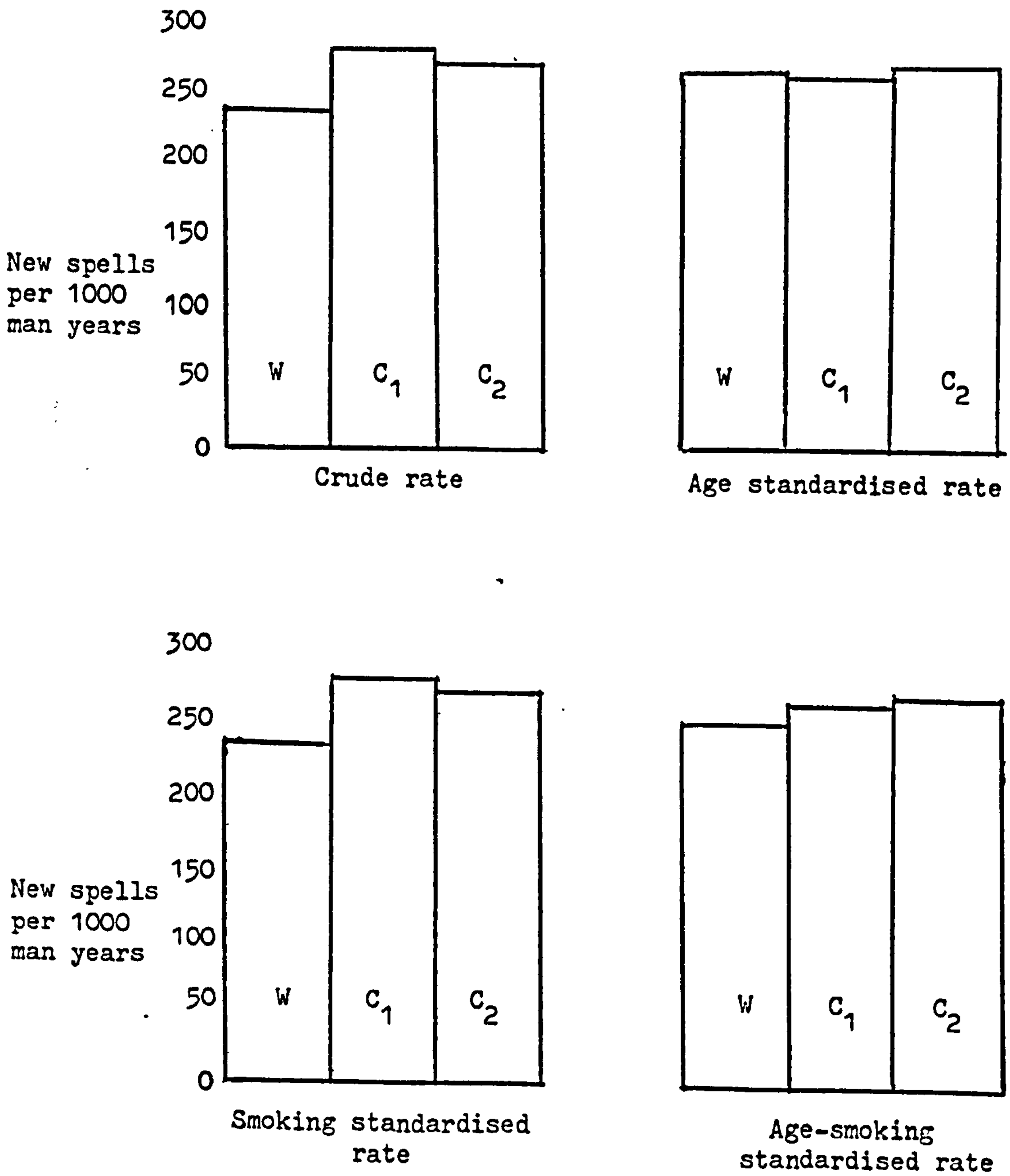
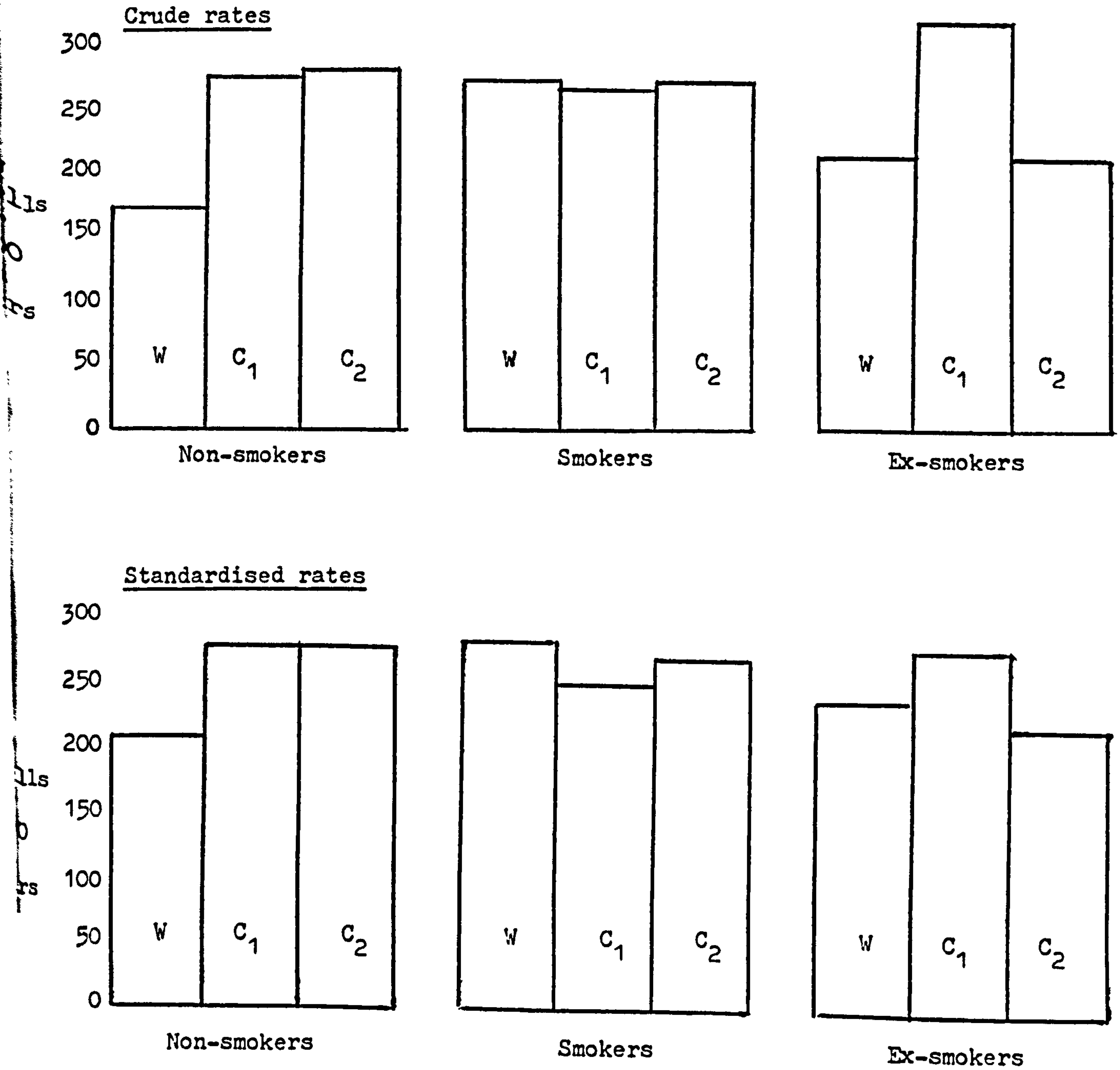


FIGURE A 32 Crude and standardised rates of new spells of absence attributed to upper respiratory tract diseases per 1000 man-years in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 33 Crude and age standardised rates of new spells of absence attributed to upper respiratory tract diseases per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 34 Inception rate per 100 persons for absence attributed to upper respiratory tract diseases in welders and controls in Dockyard Combined Population related to age

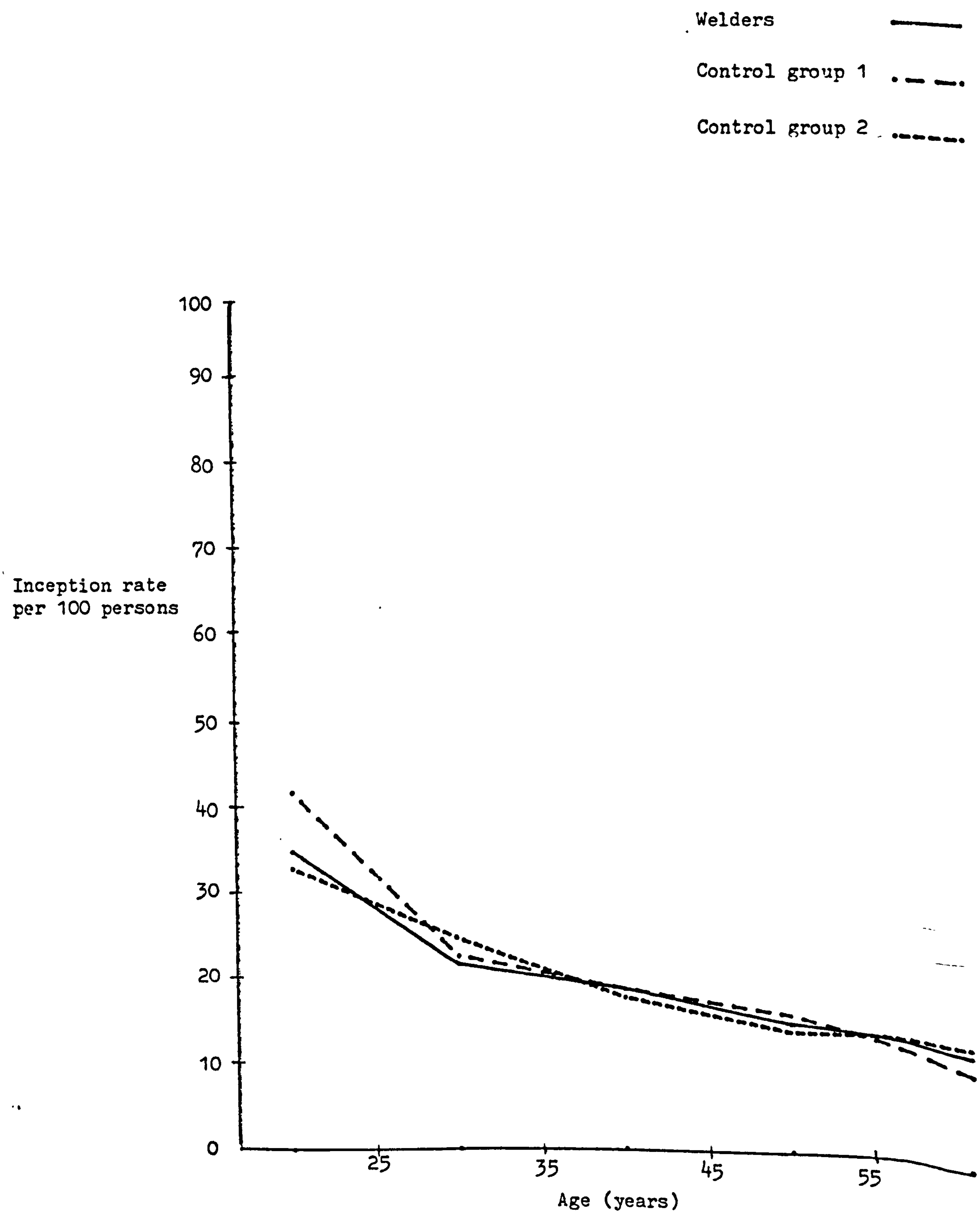
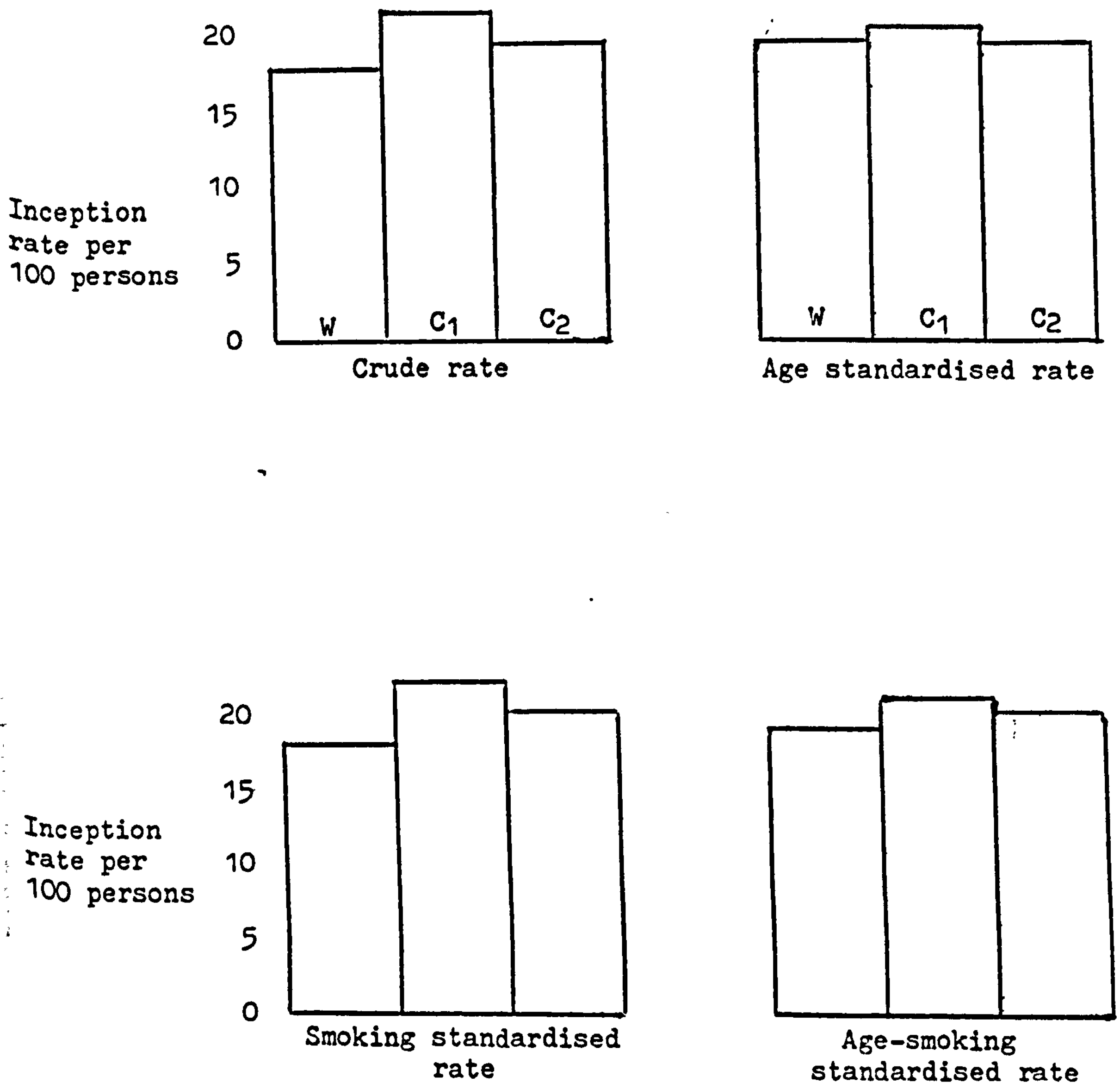


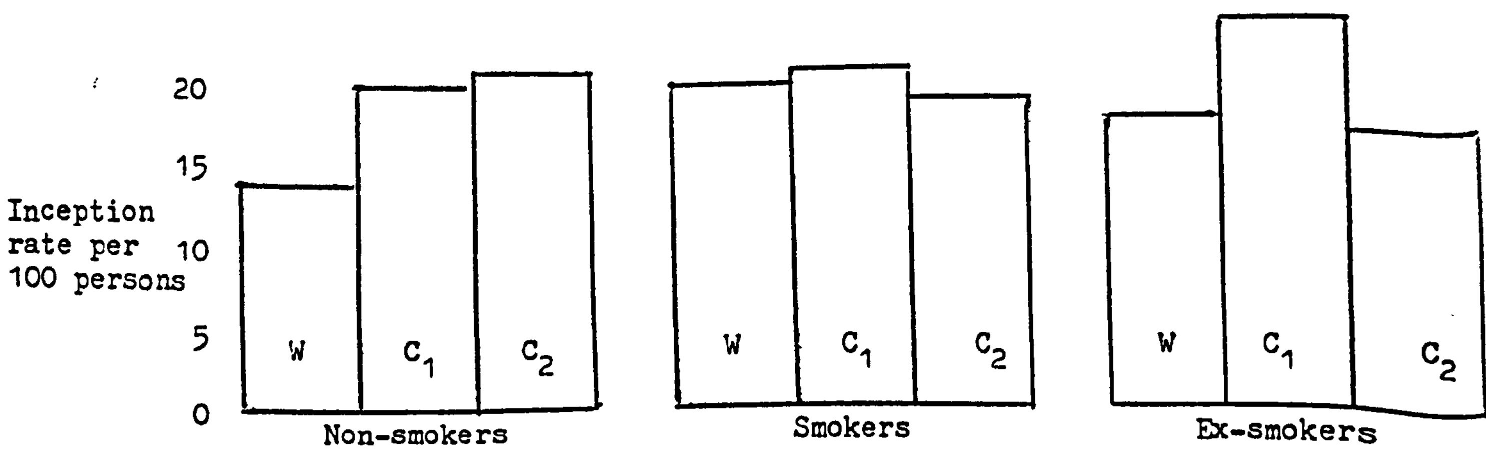
FIGURE A 35 Crude and standardised inception rate per 100 persons for absence attributed to upper respiratory tract diseases in welders and controls in Dockyard Combined Population



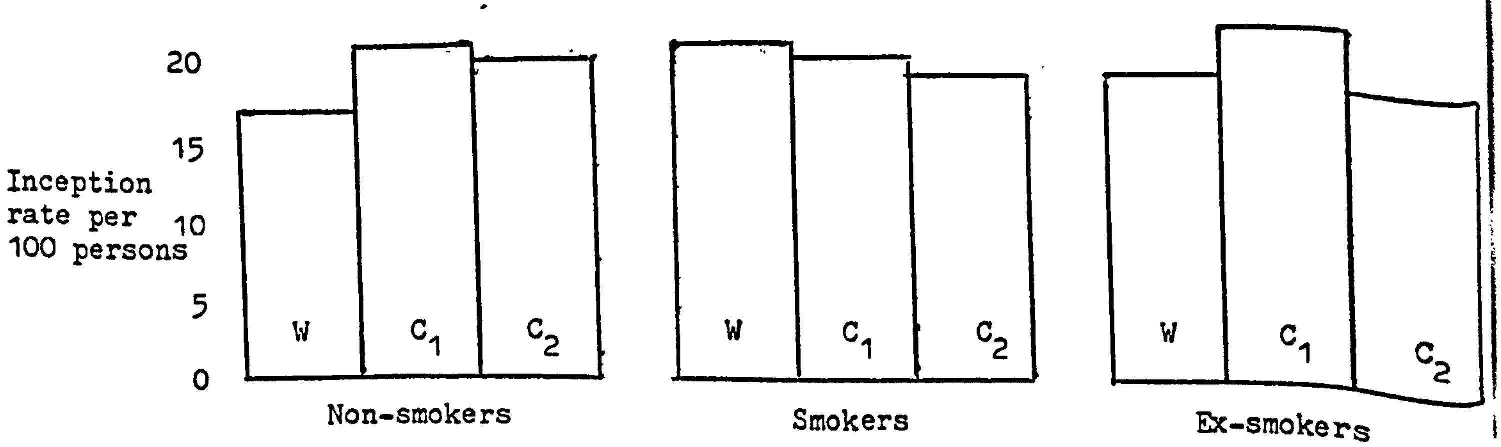
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 36 Crude and age standardised inception rates per 100 persons for absence attributed to upper respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude rates



Age standardised rates



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 37 Mean annual duration (days) of absence attributed to upper respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

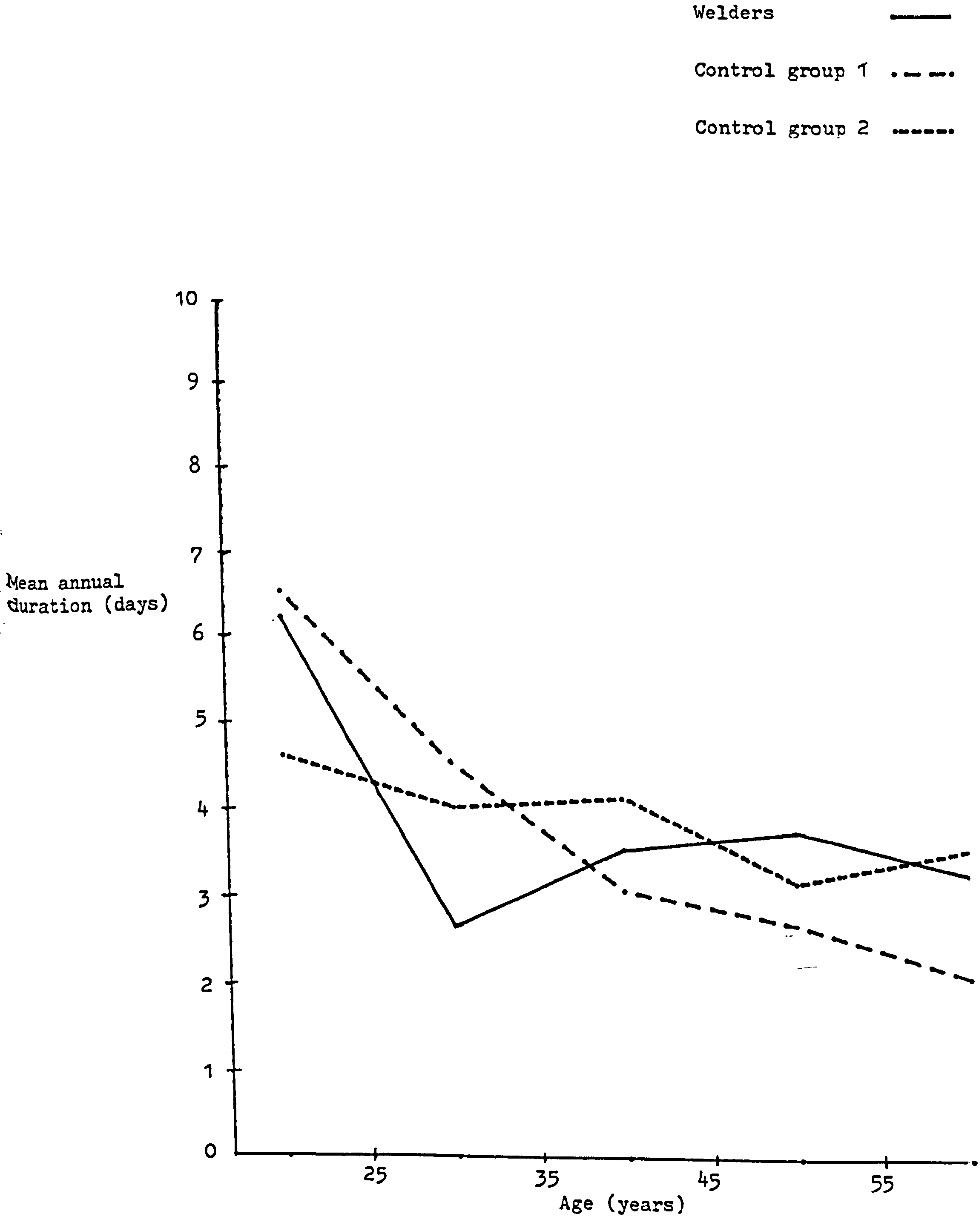
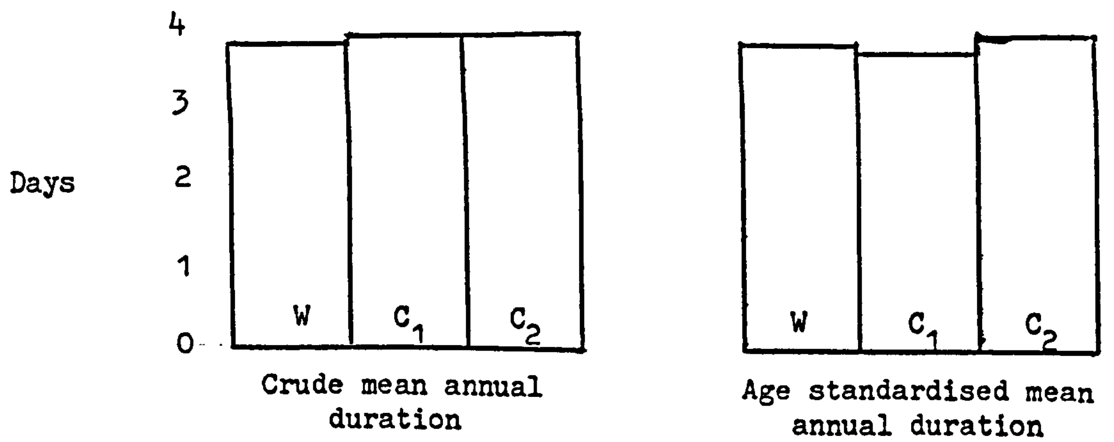
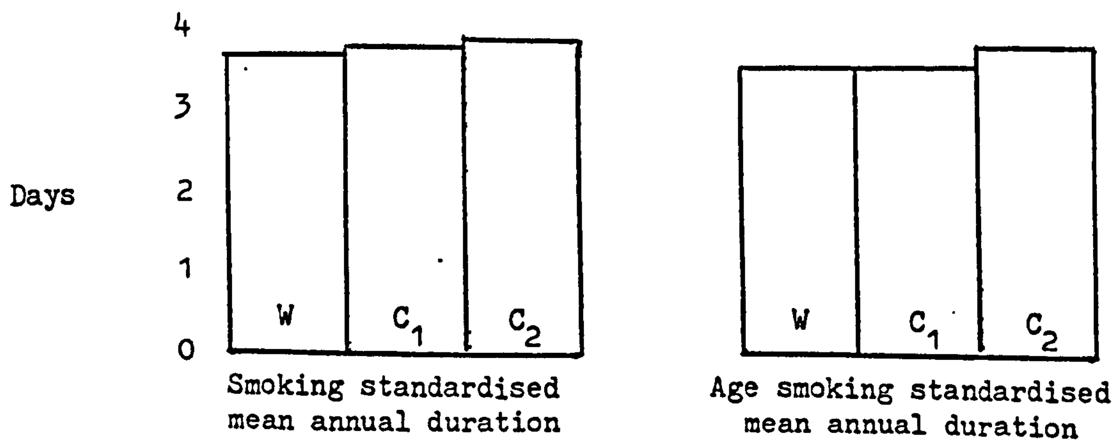


FIGURE A 38 Crude and standardised mean annual duration (days) of absence attributed to upper respiratory tract diseases in welders and controls in Dockyard Combined Population

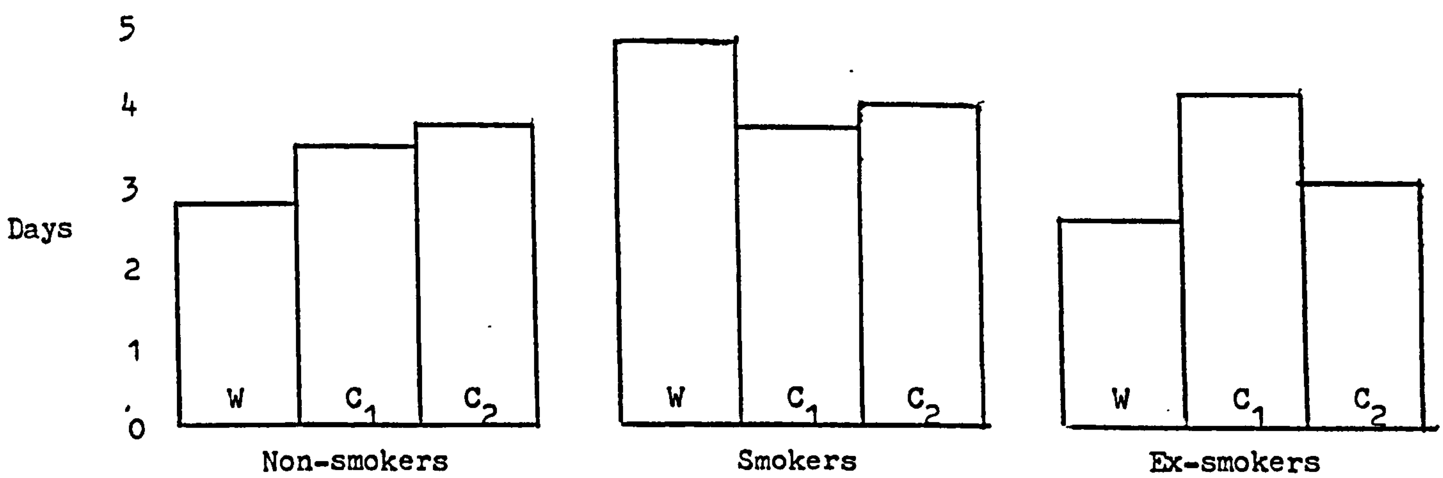




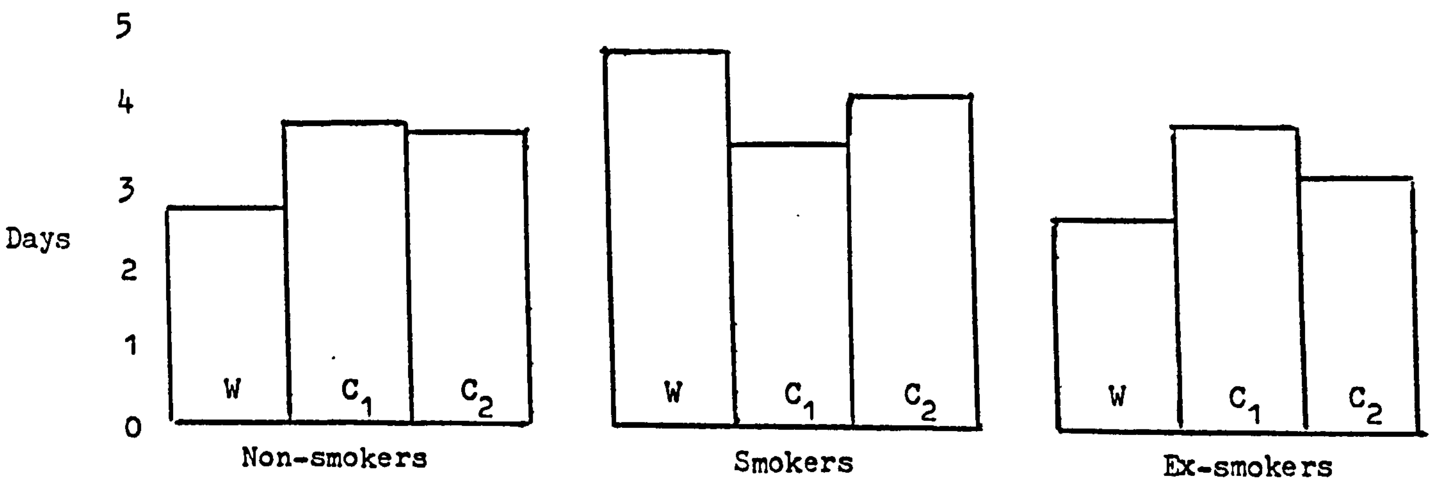
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 39 Crude and age standardised mean annual duration (days) of absence attributed to upper respiratory diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude mean annual duration



Age-standardised mean annual duration



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 40 Mean length of spell (days) of absence attributed to upper respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

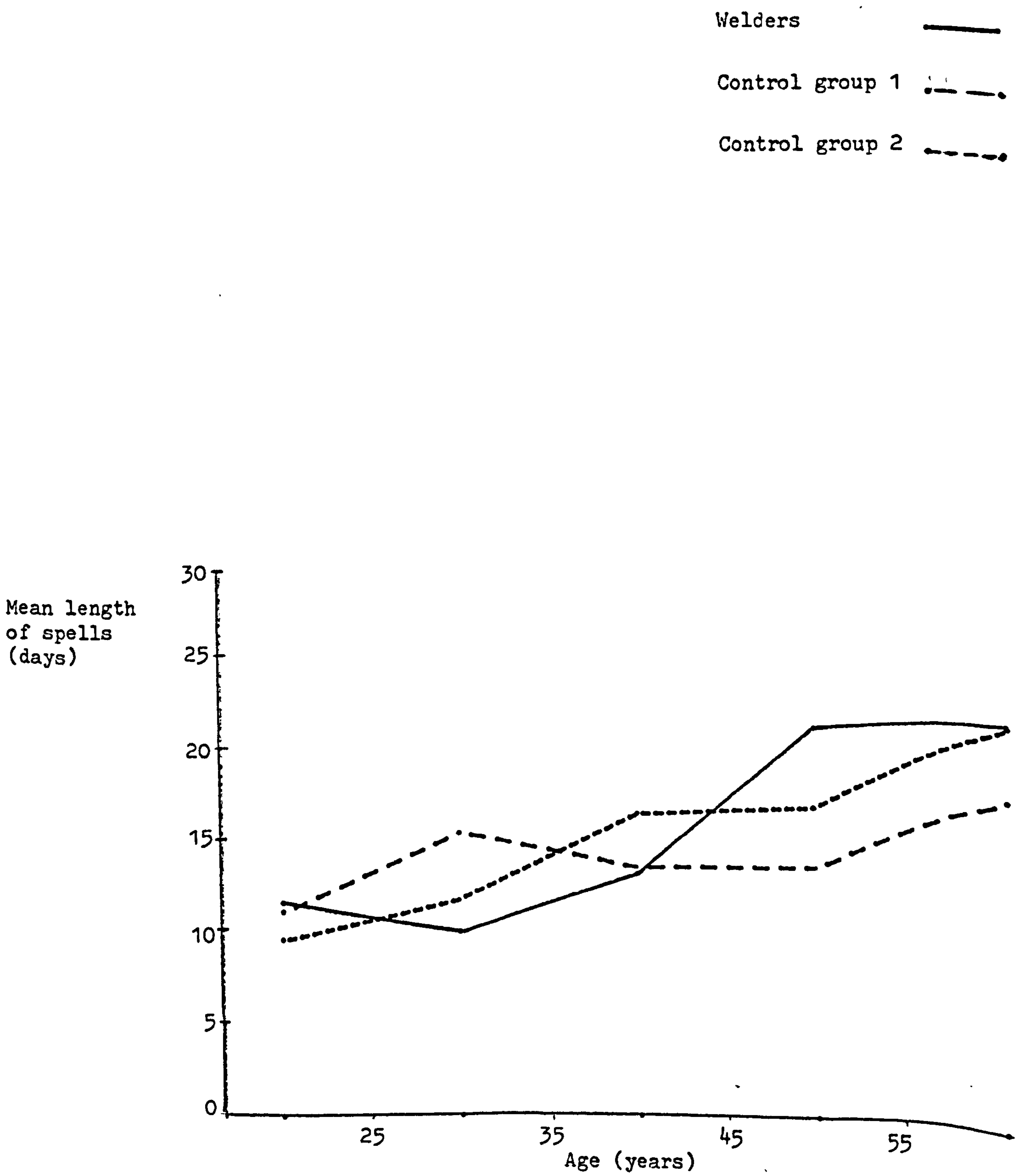
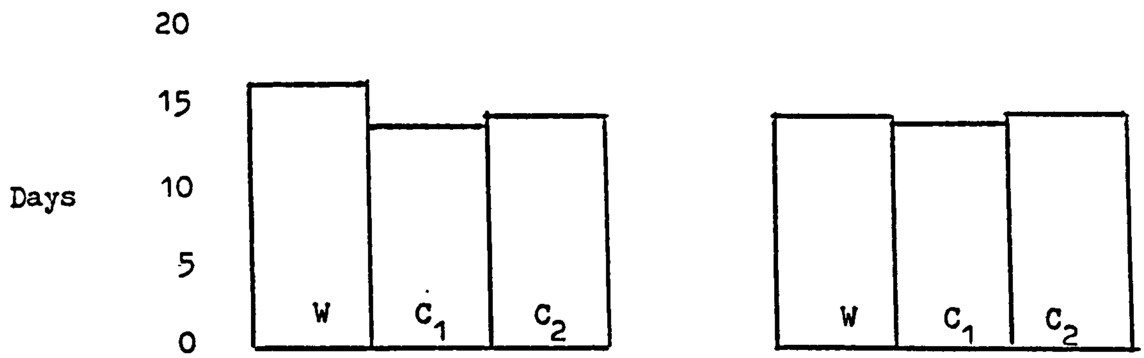
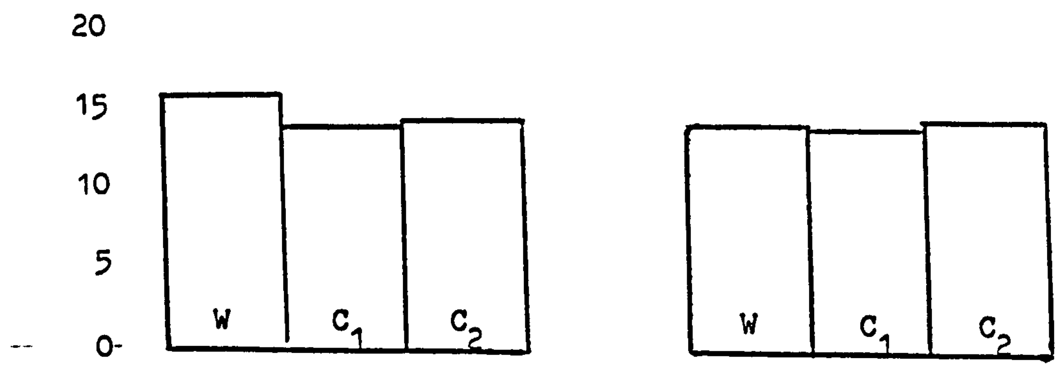


FIGURE A 41 Crude and standardised mean length of spells (days) of upper respiratory tract diseases in welders and control groups in Dockyard Combined Population



Crude mean length of spell

Age-standardised mean length of spell



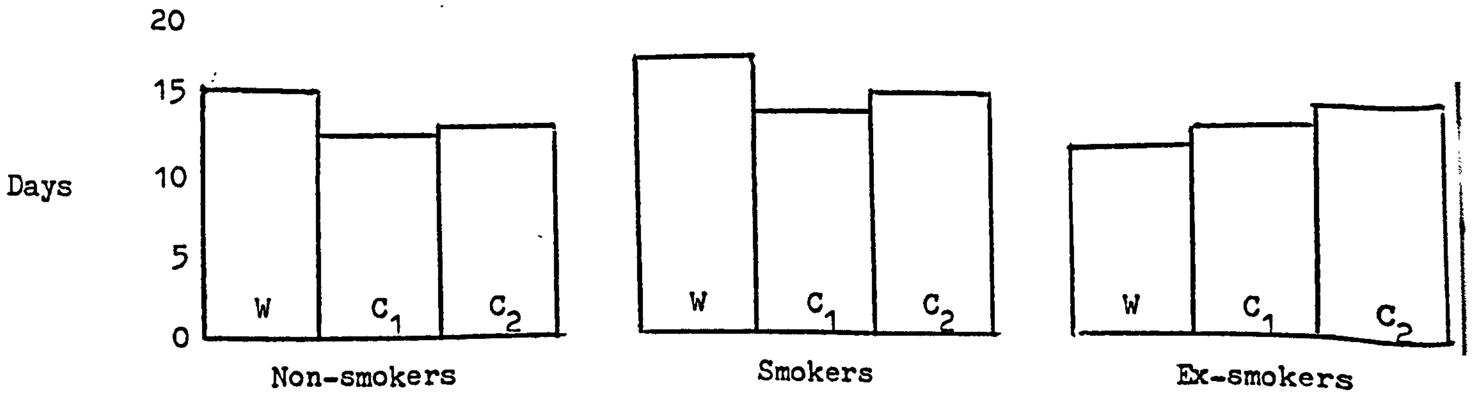
Smoking standardised Mean length of spell

Age-smoking standardised mean length of spell

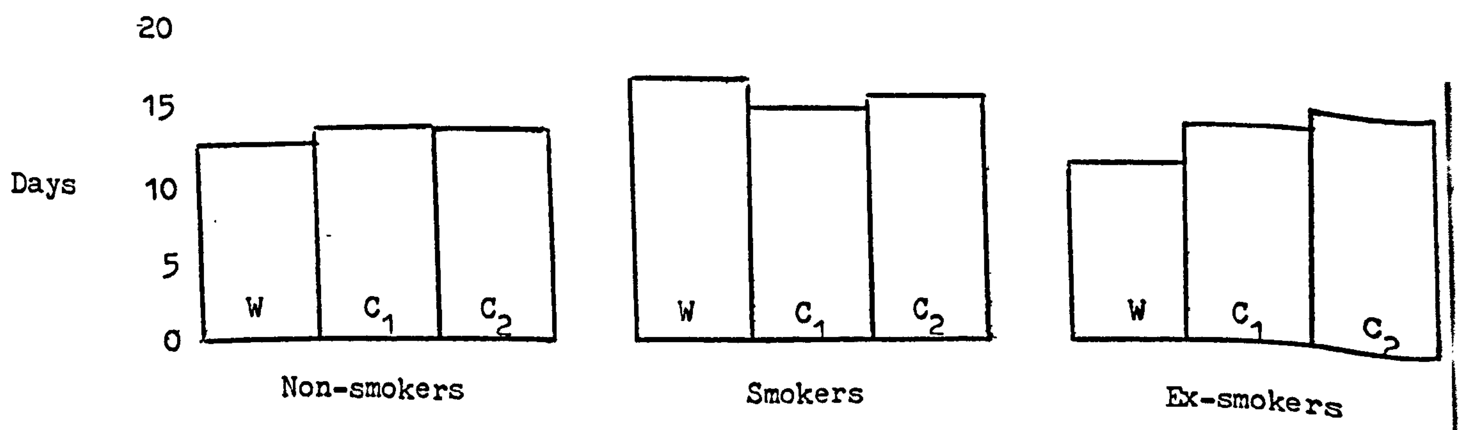
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 42 Crude and age standardised mean length of spells (days) attributed to upper respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude mean length of spells



Age-standardised mean length of spells



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 43 New spells of absence attributed to lower respiratory tract diseases per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

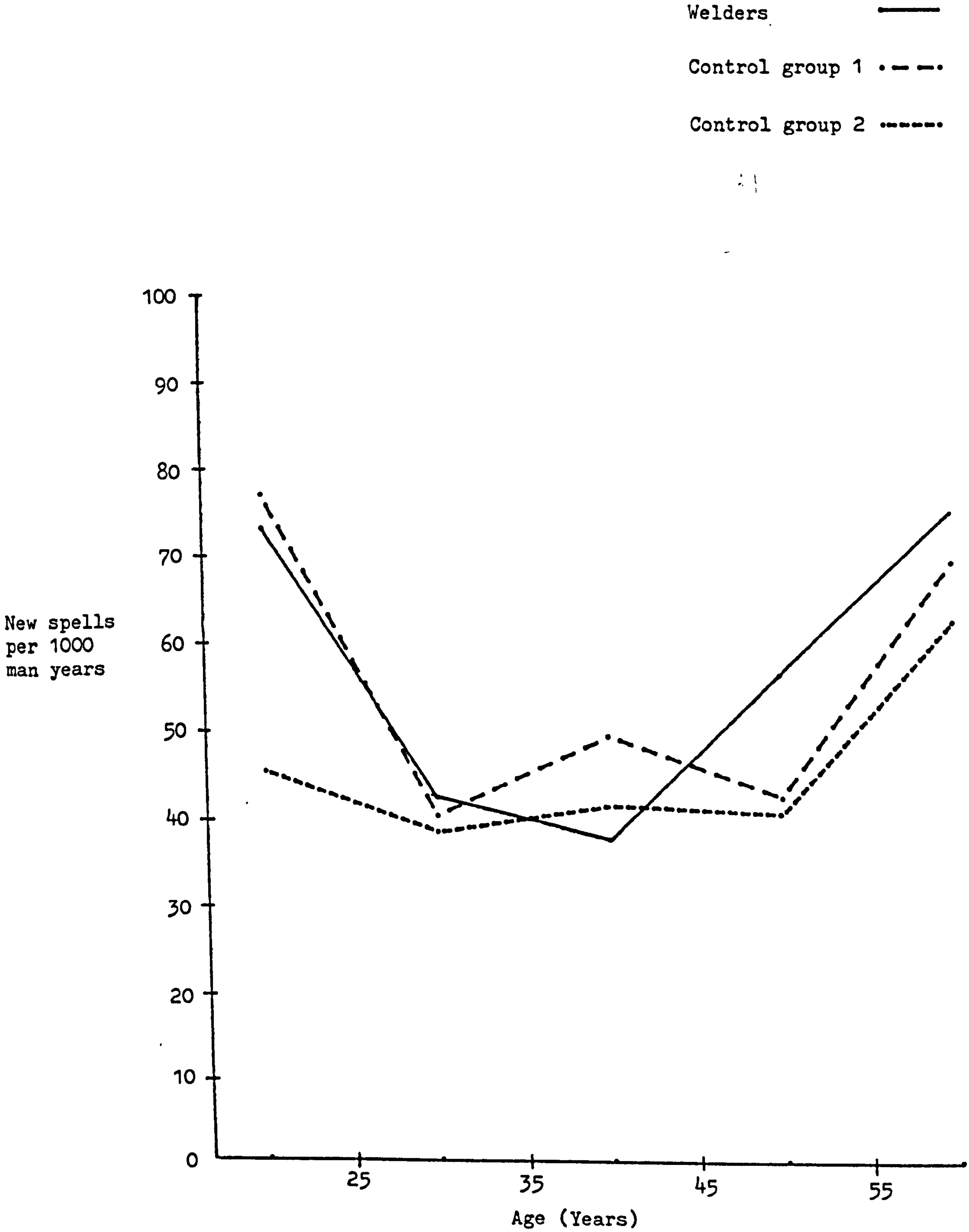
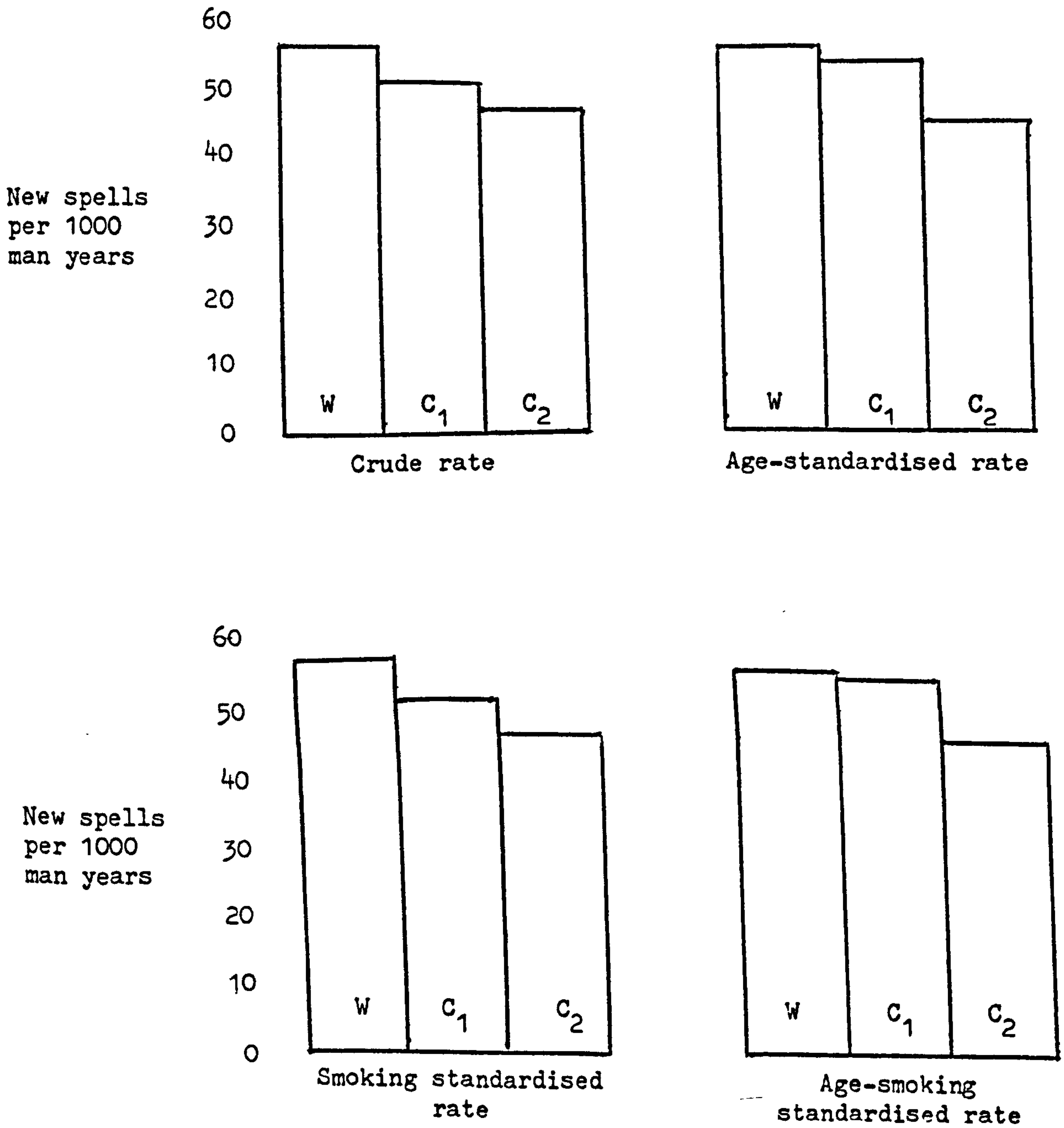


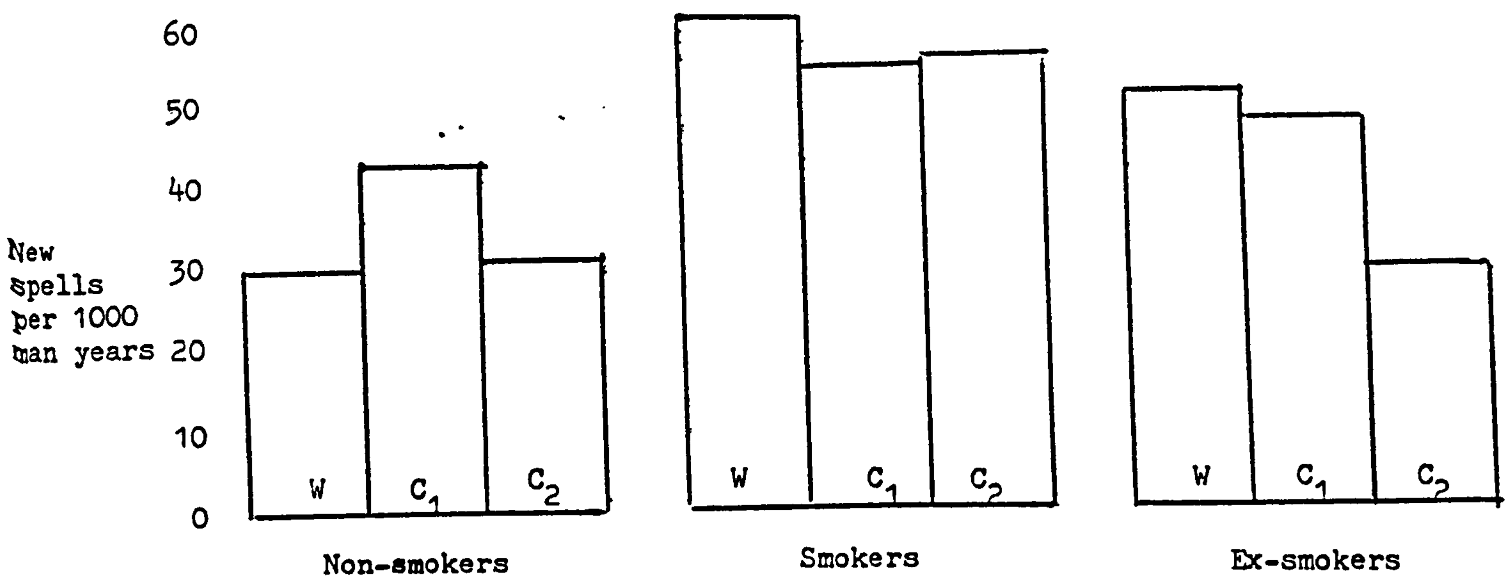
FIGURE A 44 Crude and standardised rates of new spells of absence attributed to lower respiratory tract diseases per 1000 man years in welders and control groups in Dockyard Combined Population



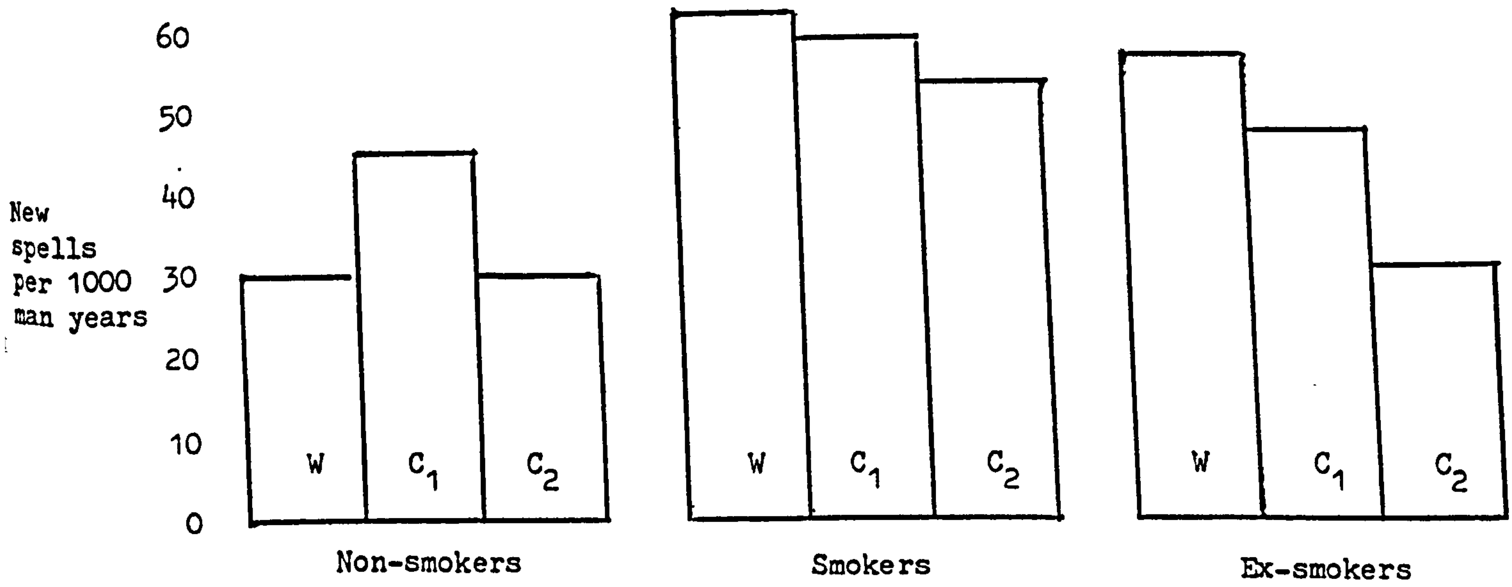
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 45 Crude and age-standardised rates of new spells of absence attributed to lower respiratory tract diseases per 1000 man-years in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude rates



Age standardised rates



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 46 Inception rate per 100 persons for absence attributed to lower respiratory tract diseases in welders and controls in Dockyard Combined Population related to age

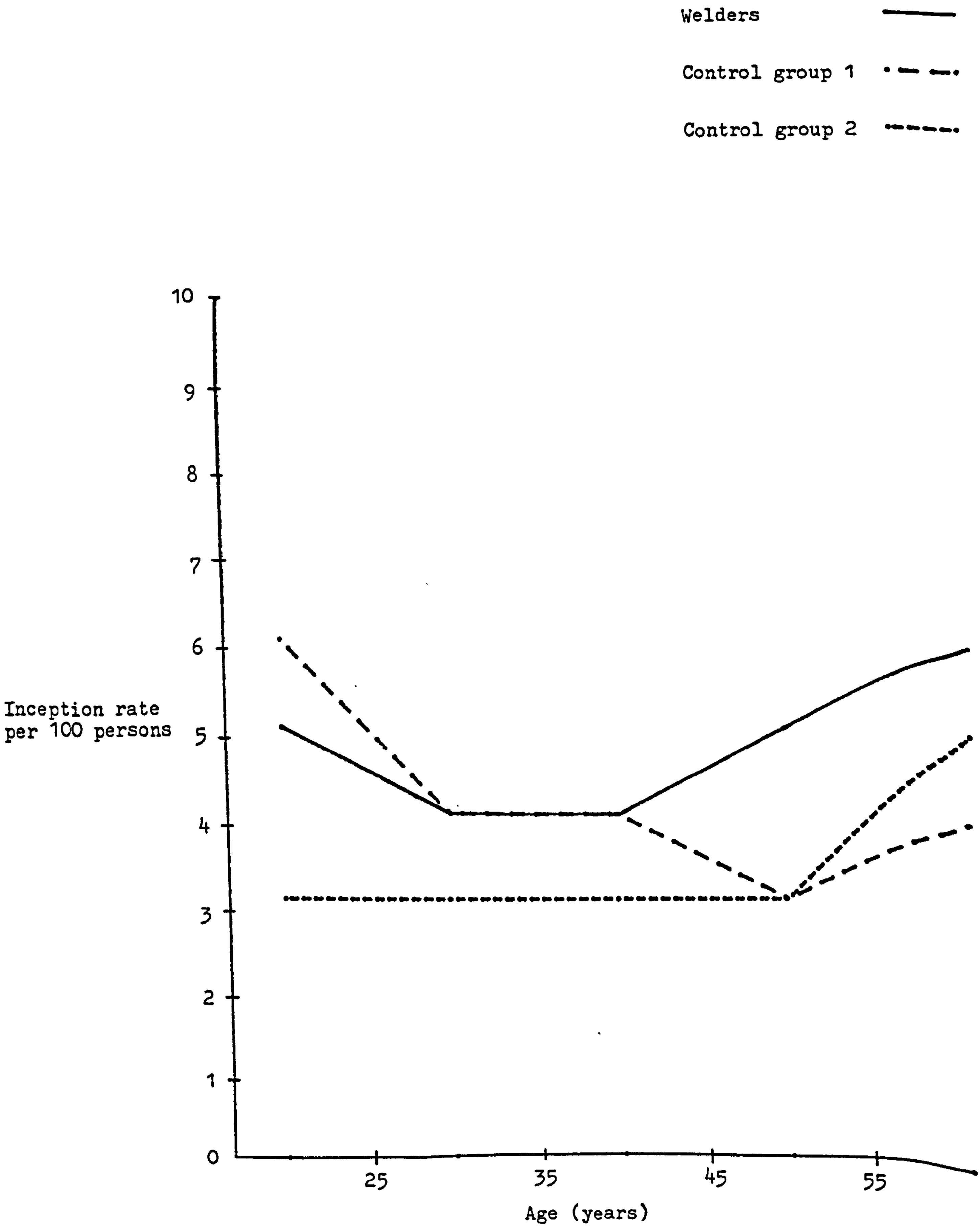
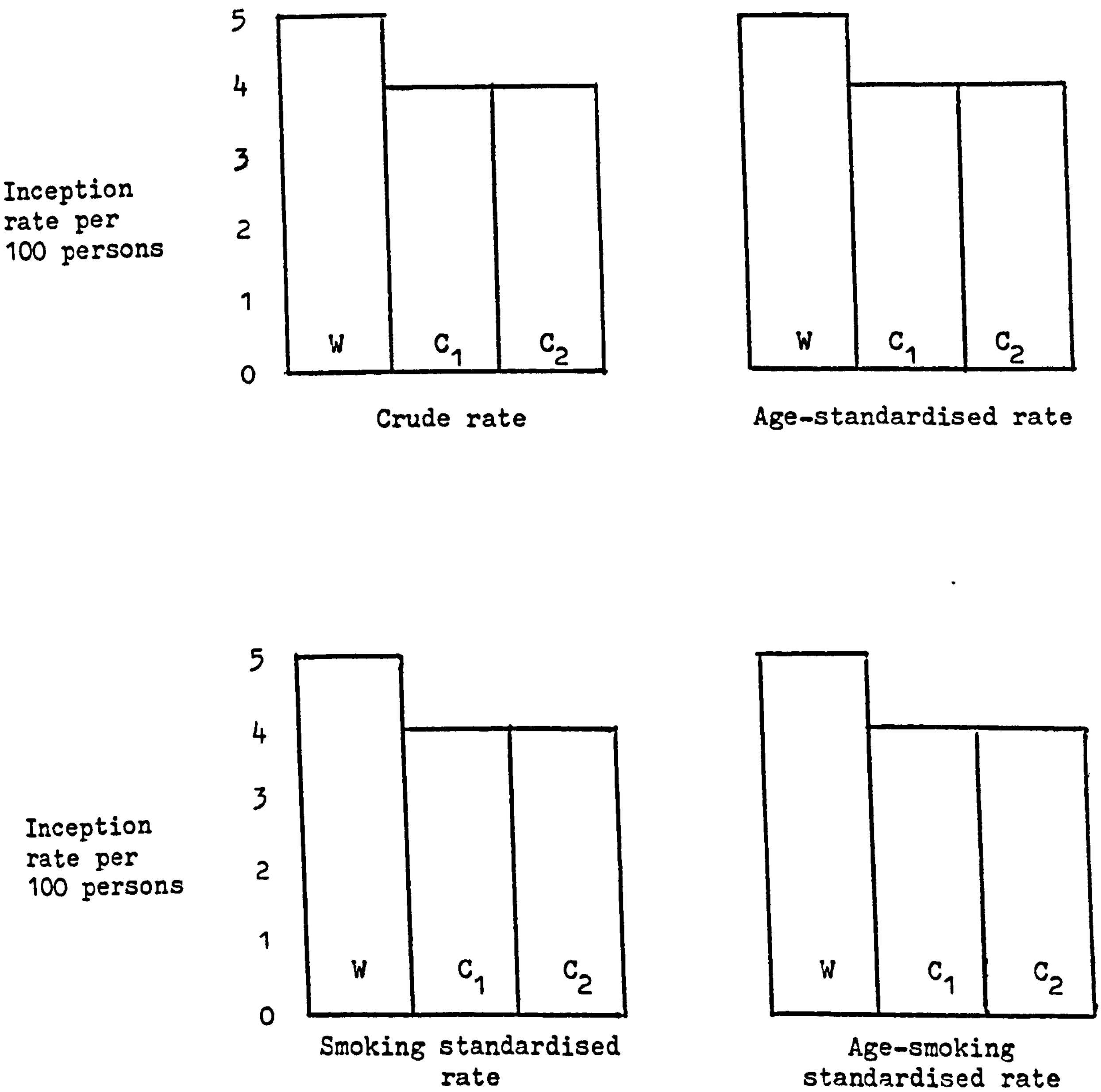


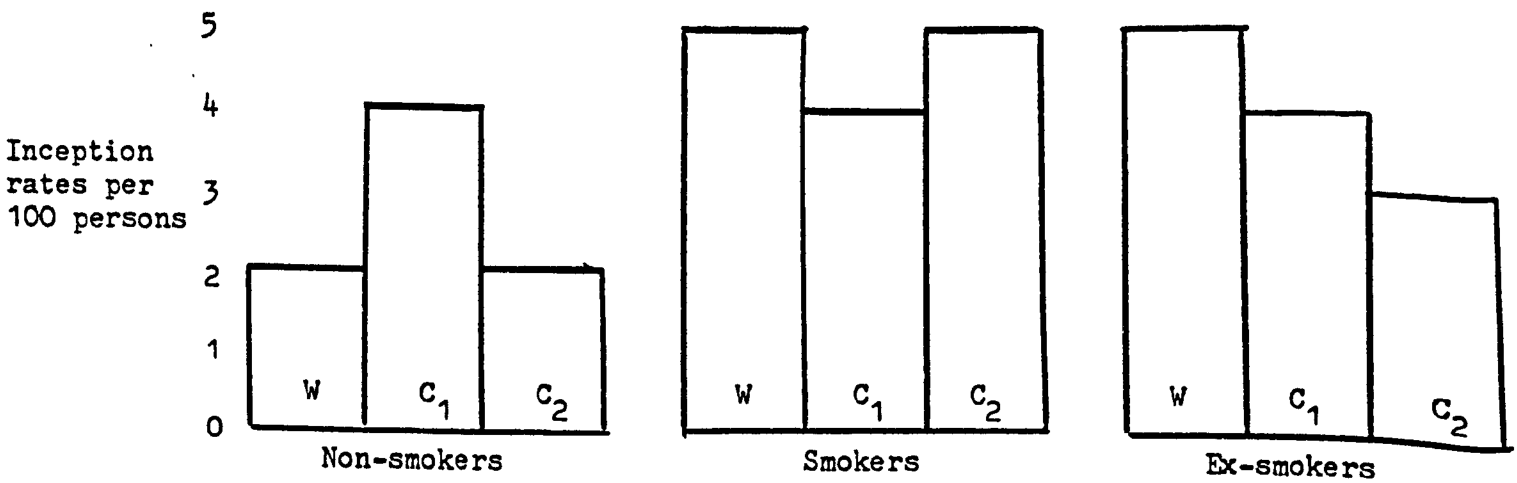
FIGURE A 47 Crude and standardised inception rate per 100 persons for absence attributed to lower respiratory tract diseases in welders and controls in Dockyard Combined Population



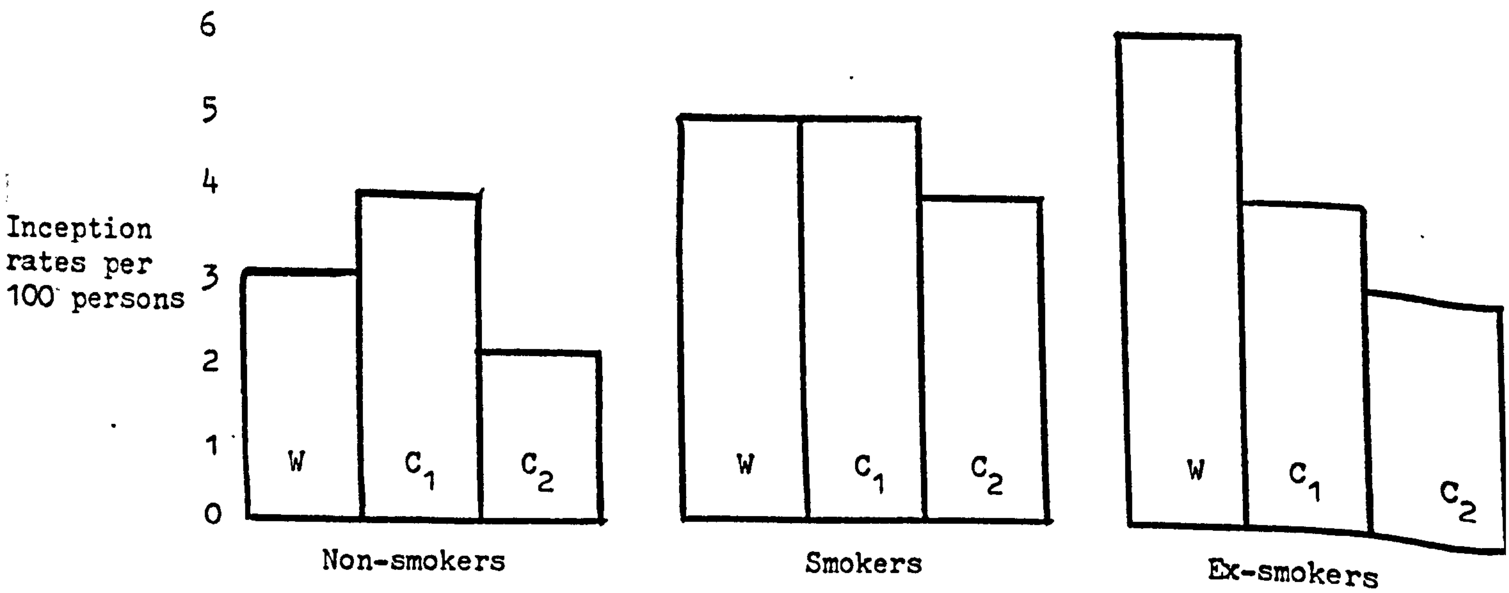
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A48 Crude and age standardised inception rates per 100 persons for absence attributed to lower respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude rates



Age standardised rates



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A.49 Mean annual duration (days) of absence attributed to lower respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

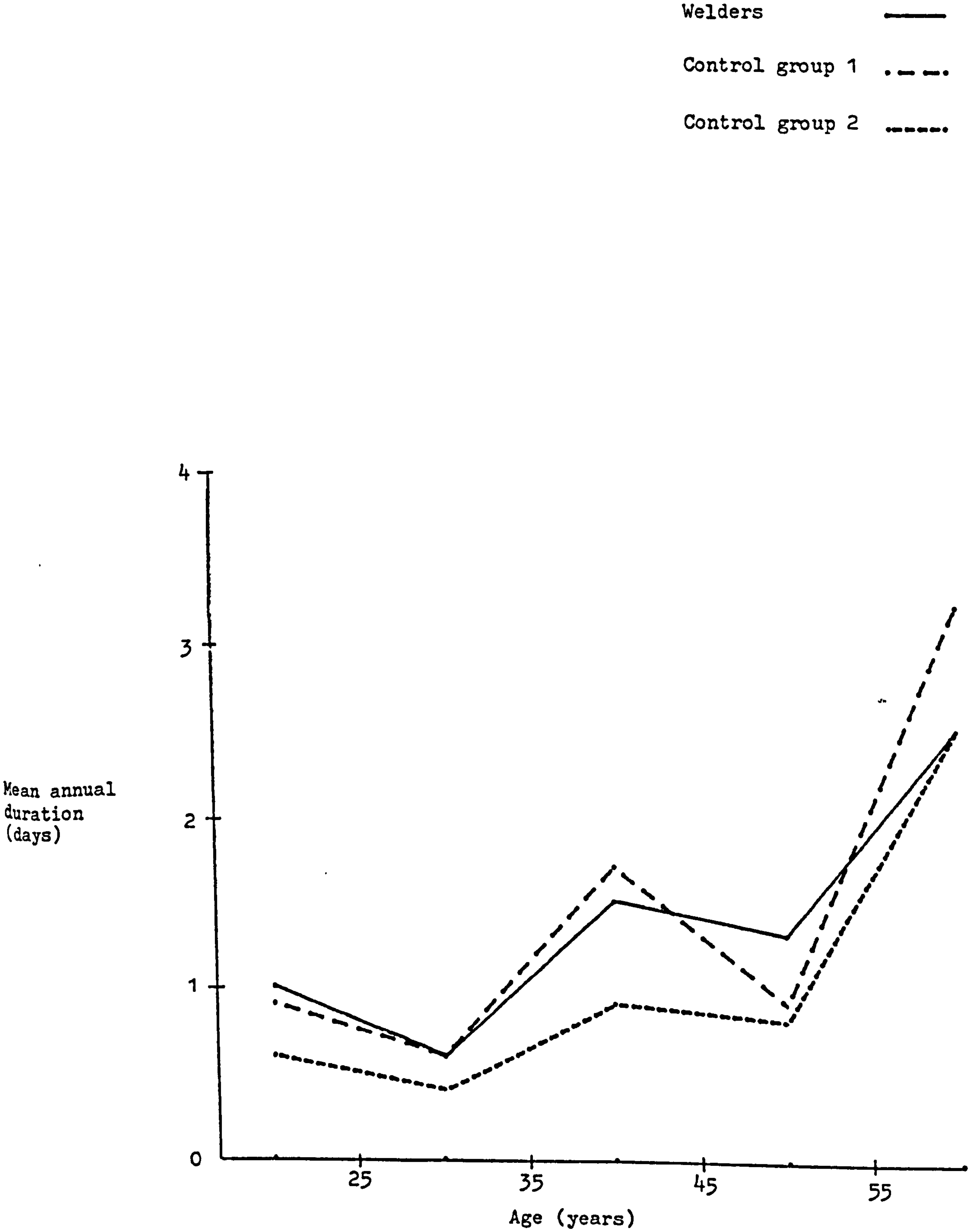
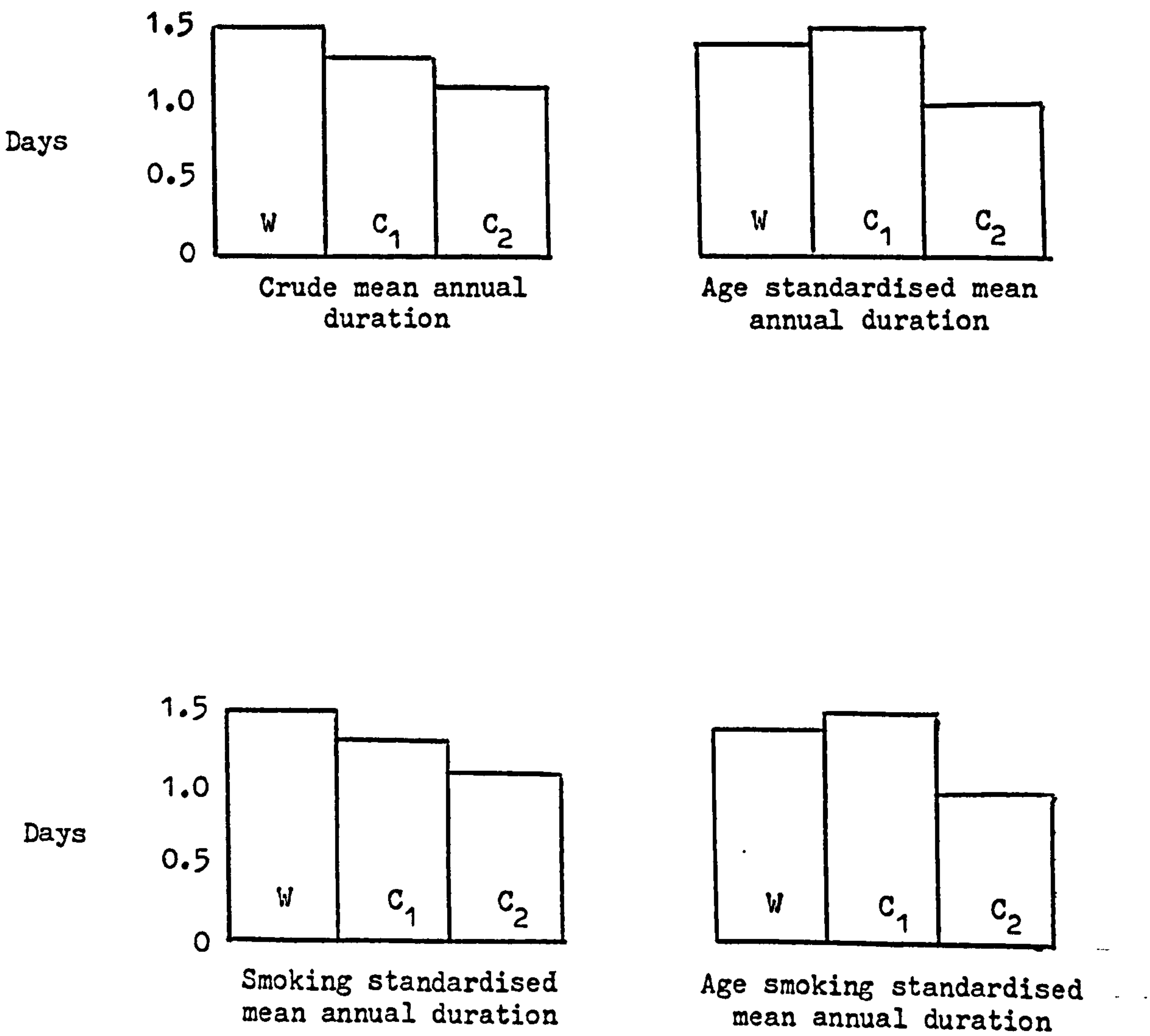


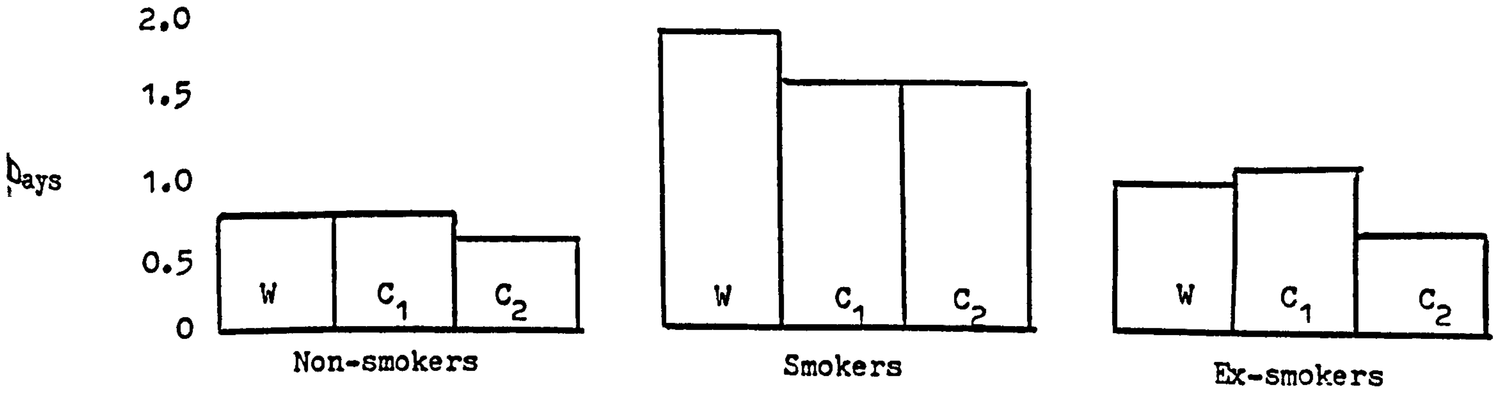
FIGURE A.50 Crude and standardised mean annual duration (days) of absence attributed to lower respiratory tract diseases in welders and controls in Dockyard Combined Population



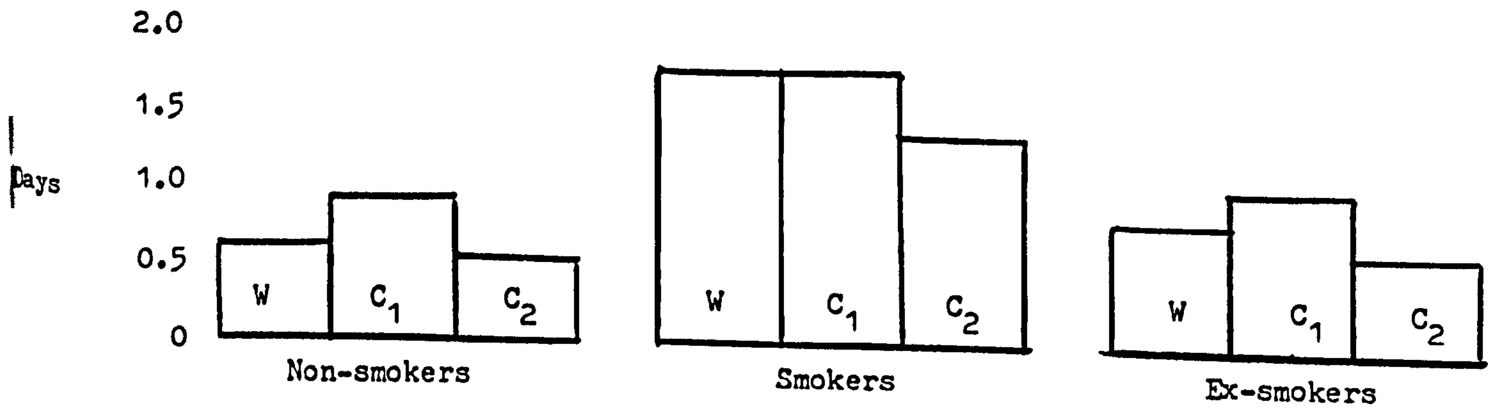
W = Welders . C_1 = Control group 1 C_2 = Control group 2

FIGURE A 51 Crude and age-standardised mean annual duration (days) of absence attributed to lower respiratory disease in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude mean annual duration



Age standardised mean annual duration



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 52 Mean length of spell (days) of absence attributed to lower respiratory tract diseases in welders and control groups in Dockyard Combined Population related to age

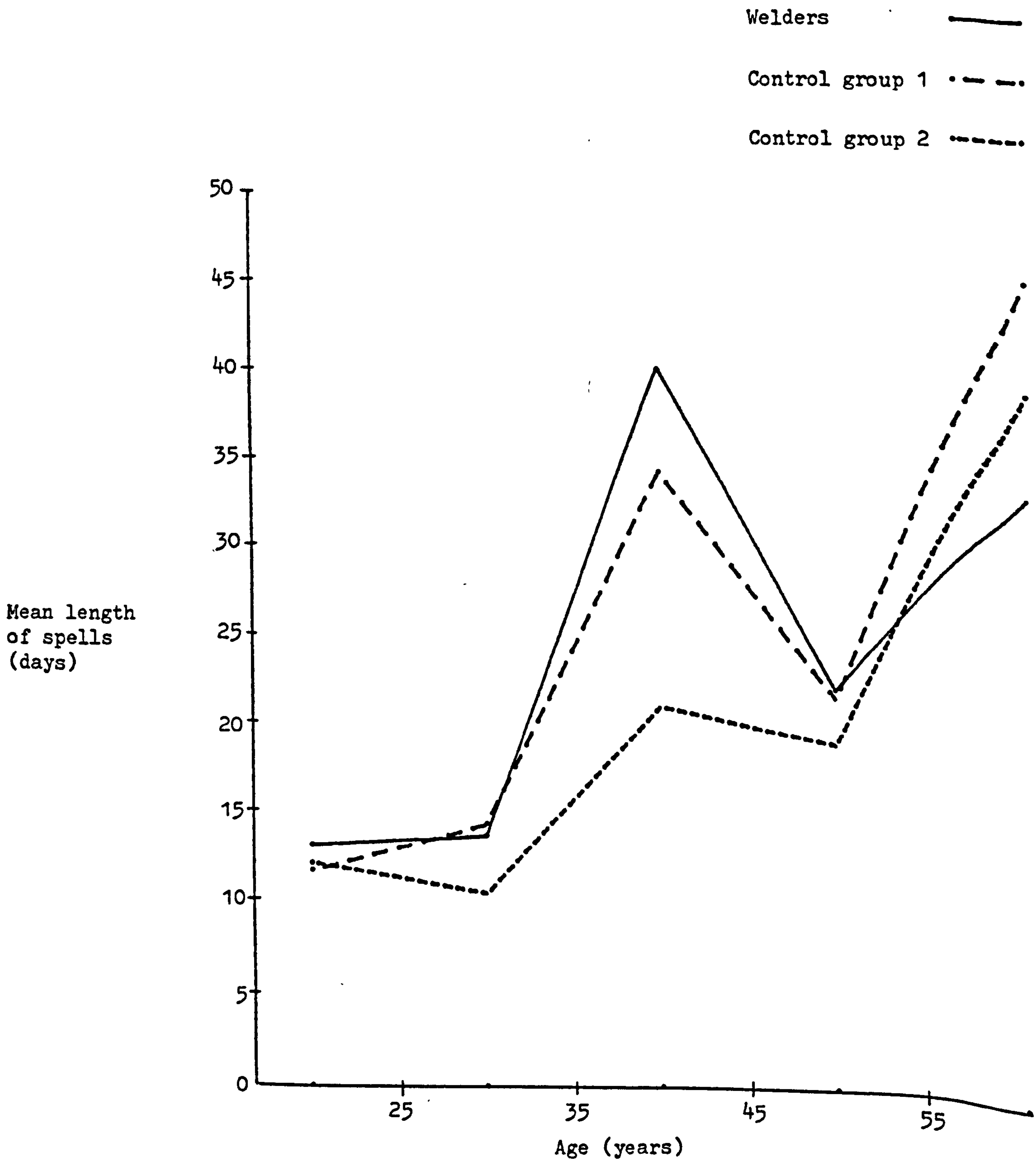
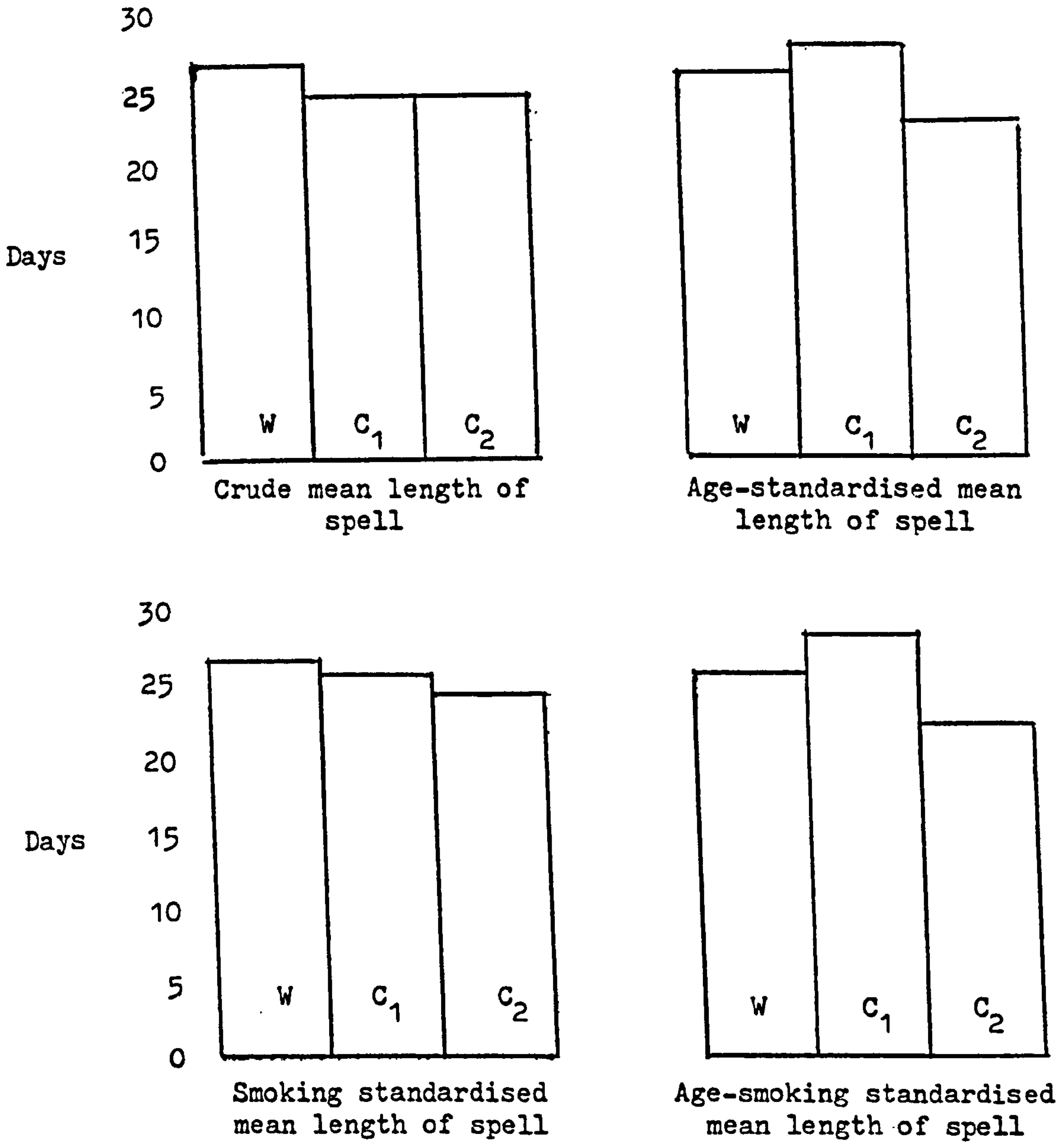
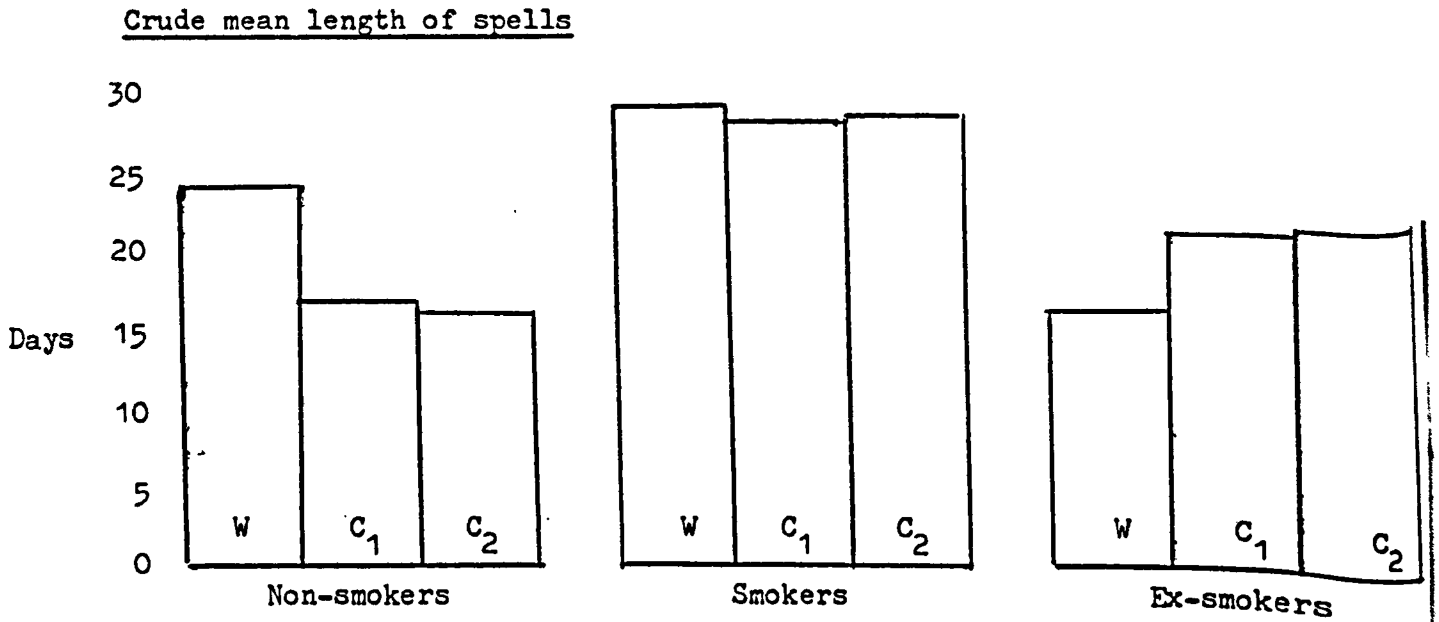


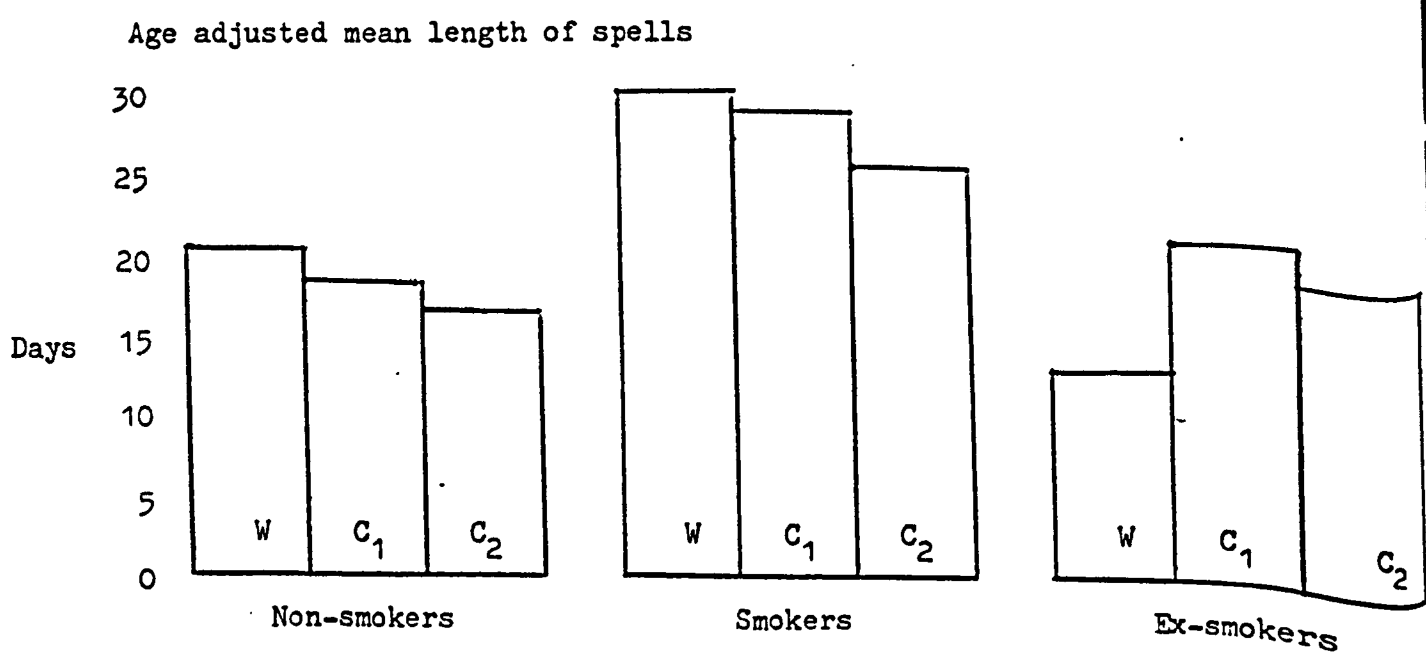
FIGURE A.53 Crude and standardised mean length of spells (days) of absence attributed to lower respiratory tract diseases in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 54 Crude and age standardised mean length of spells (days) of absence attributed to lower respiratory tract diseases in non-smokers, smokers and ex-smokers in welders and control groups in the Dockyard Combined Population





W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 55 New spells of absence attributed to diseases other than respiratory per 1000 man-years in welders and control groups in Dockyard Combined Population related to age

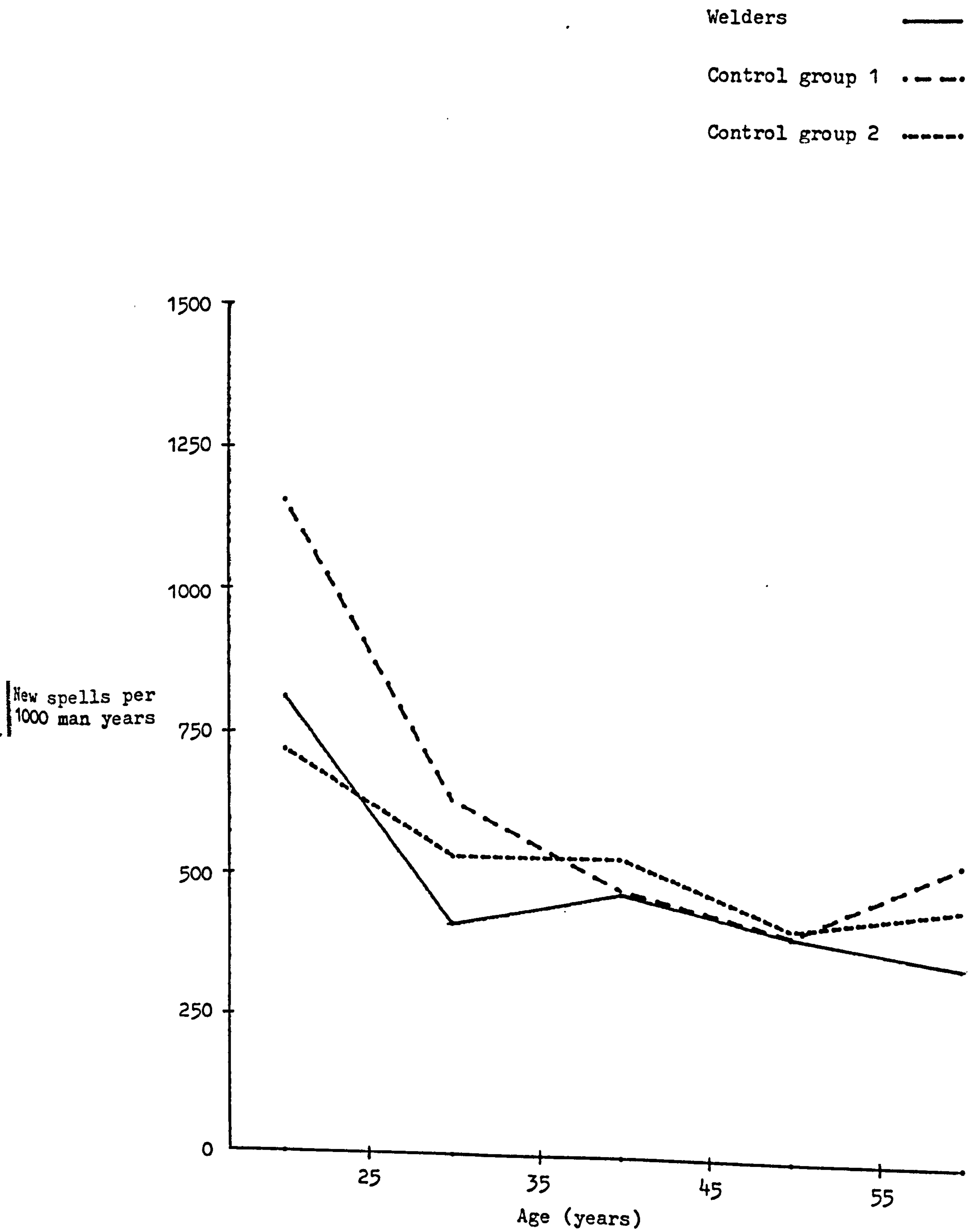
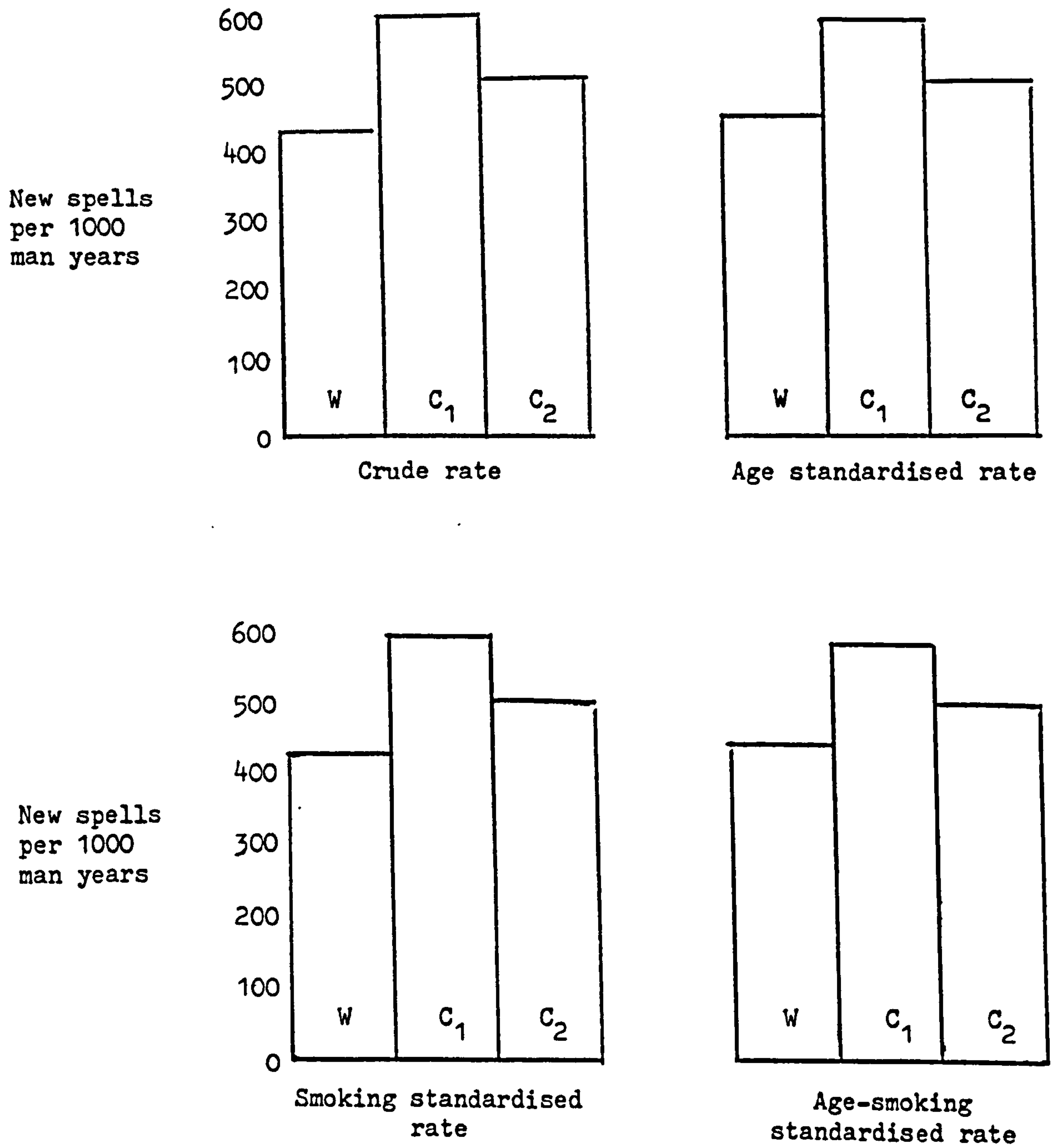
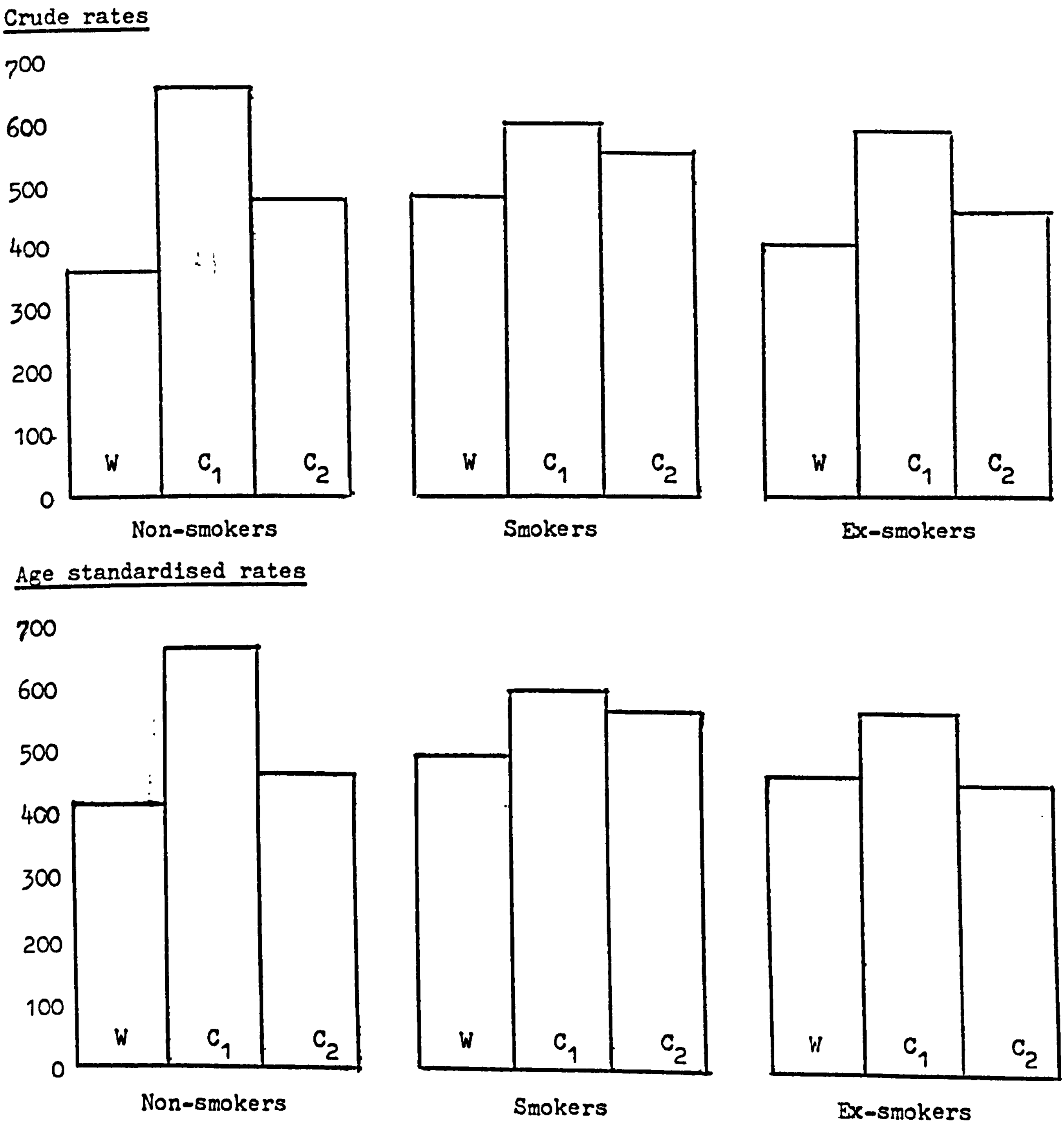


FIGURE A56 Crude and standardised rates of new spells of absence attributed to diseases other than respiratory per 1000 man years in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control groul 2

FIGURE A 57 Crude and age standardised rates of new spells of absence attributed to diseases other than respiratory per 1000 man years in non-smokers, smokers and ex-smokers in welders and controls in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A58 Inception rate per 100 persons for absence attributed to diseases other than respiratory in welders and controls in Dockyard Combined Population related to age

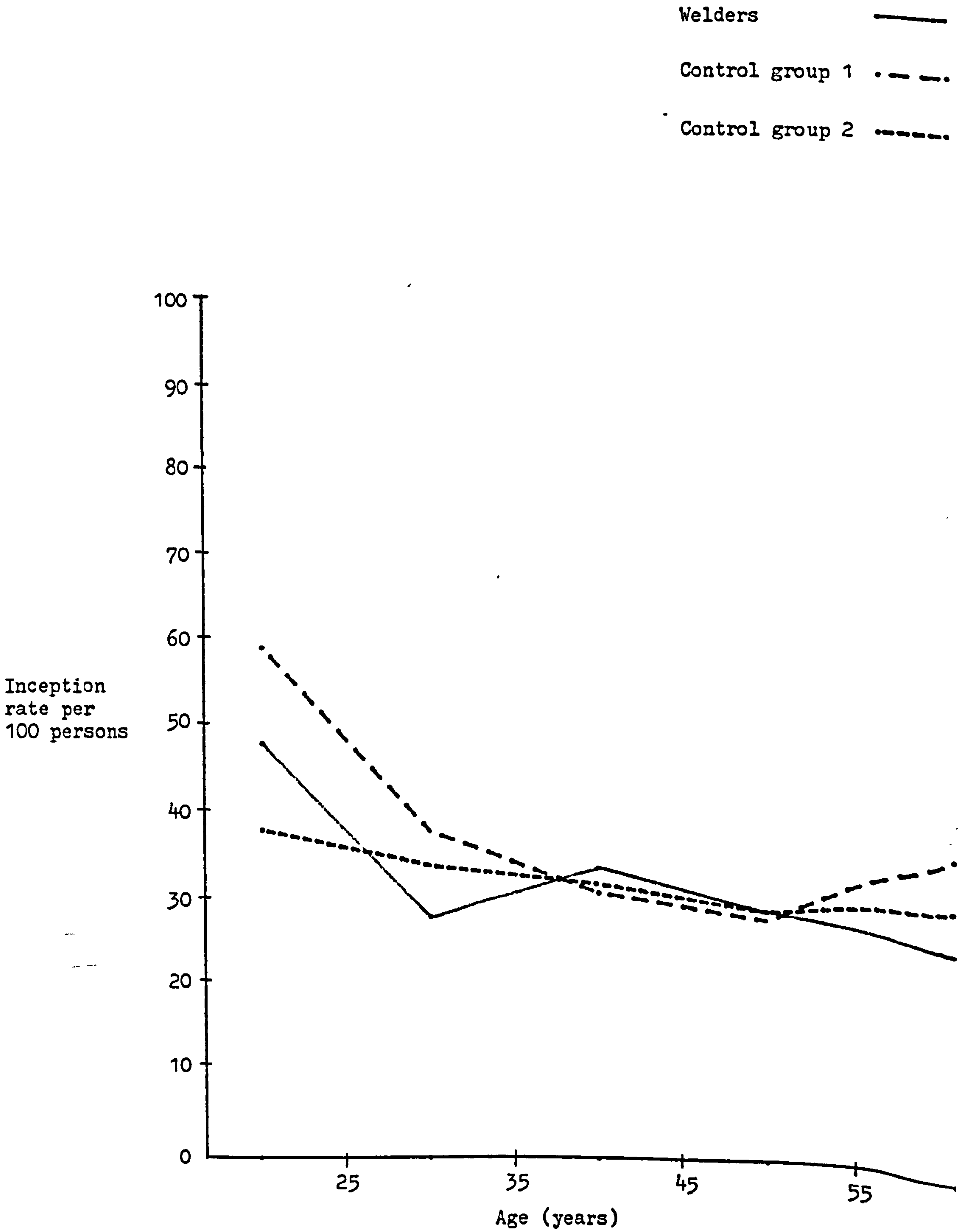
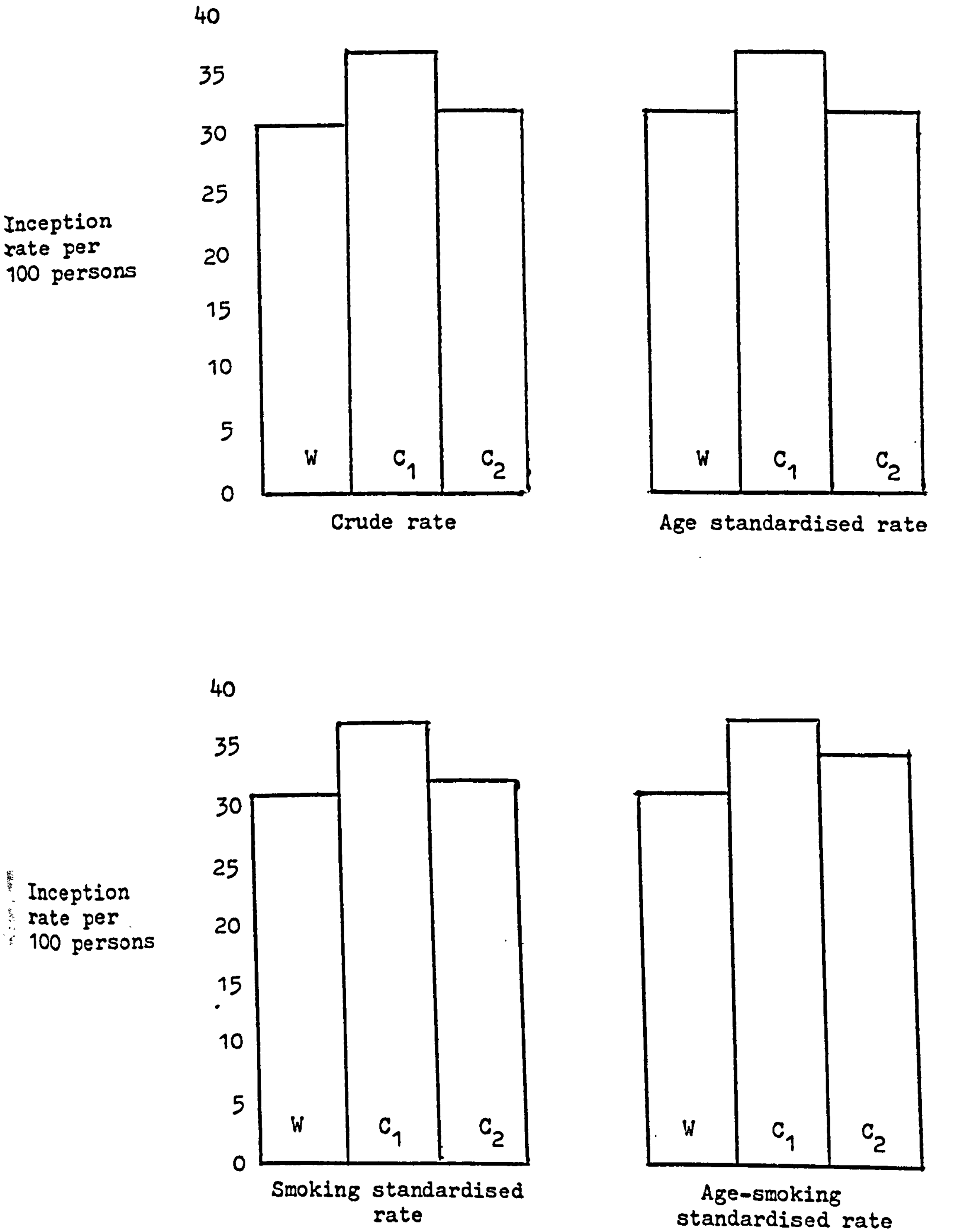
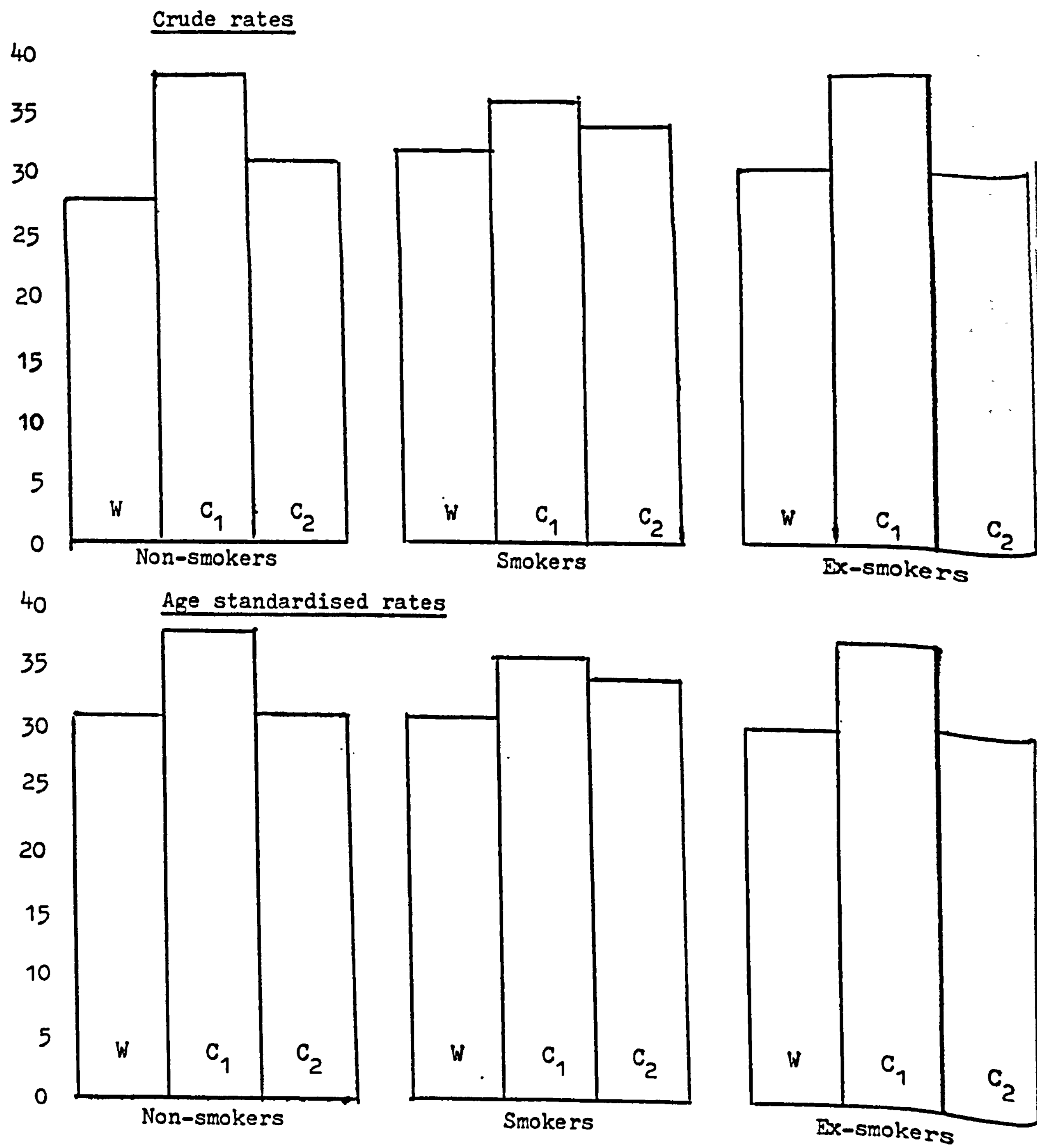


FIGURE A 59 Crude and standardised inception rate per 100 persons for absence attributed to diseases other than respiratory in welders and controls in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 60 Crude and age standardised inception rates per 100 persons for absence attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 61 Mean length of spell (days) of absence attributed to diseases other than respiratory in welders and control groups in Dockyard Combined Population related to age

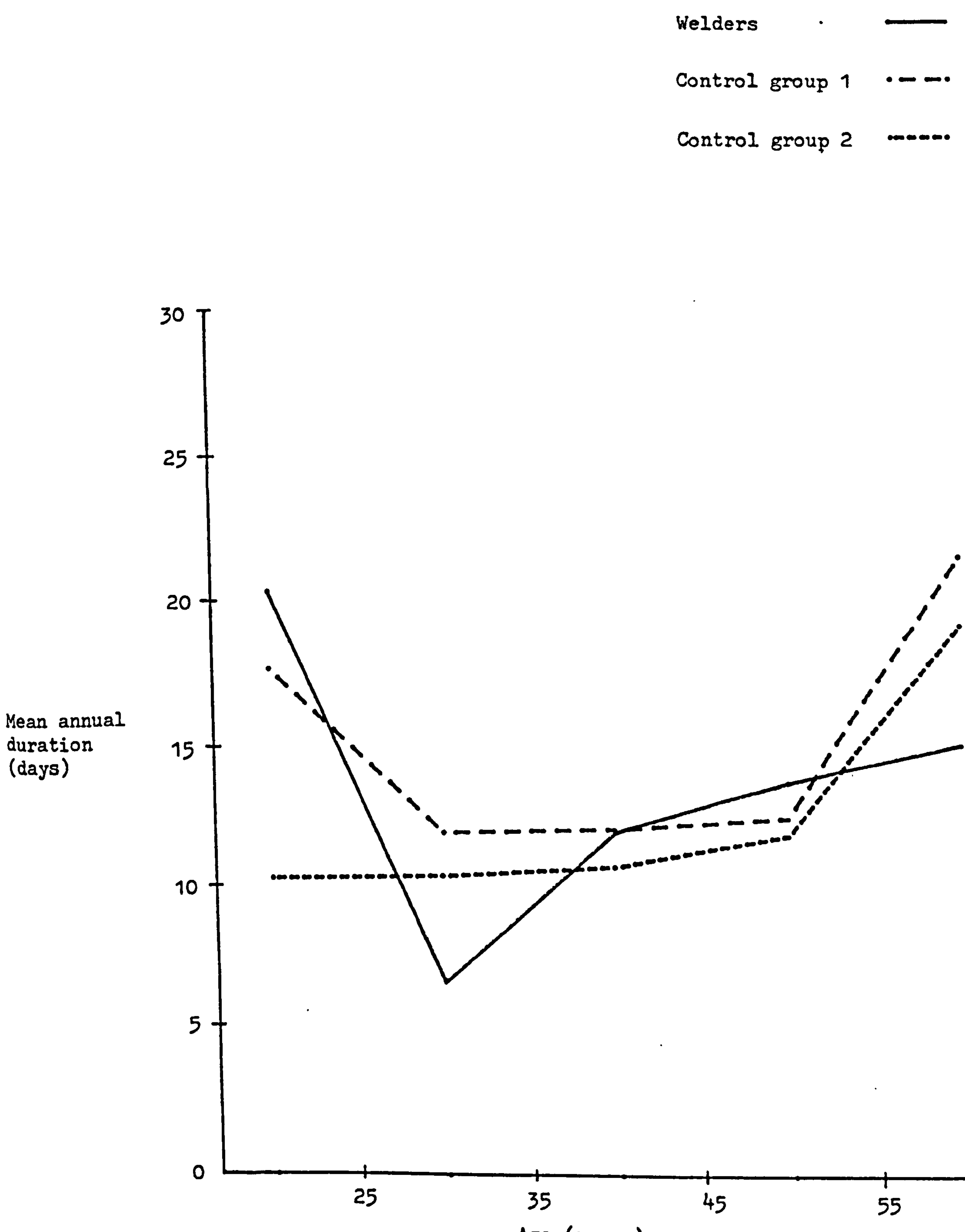
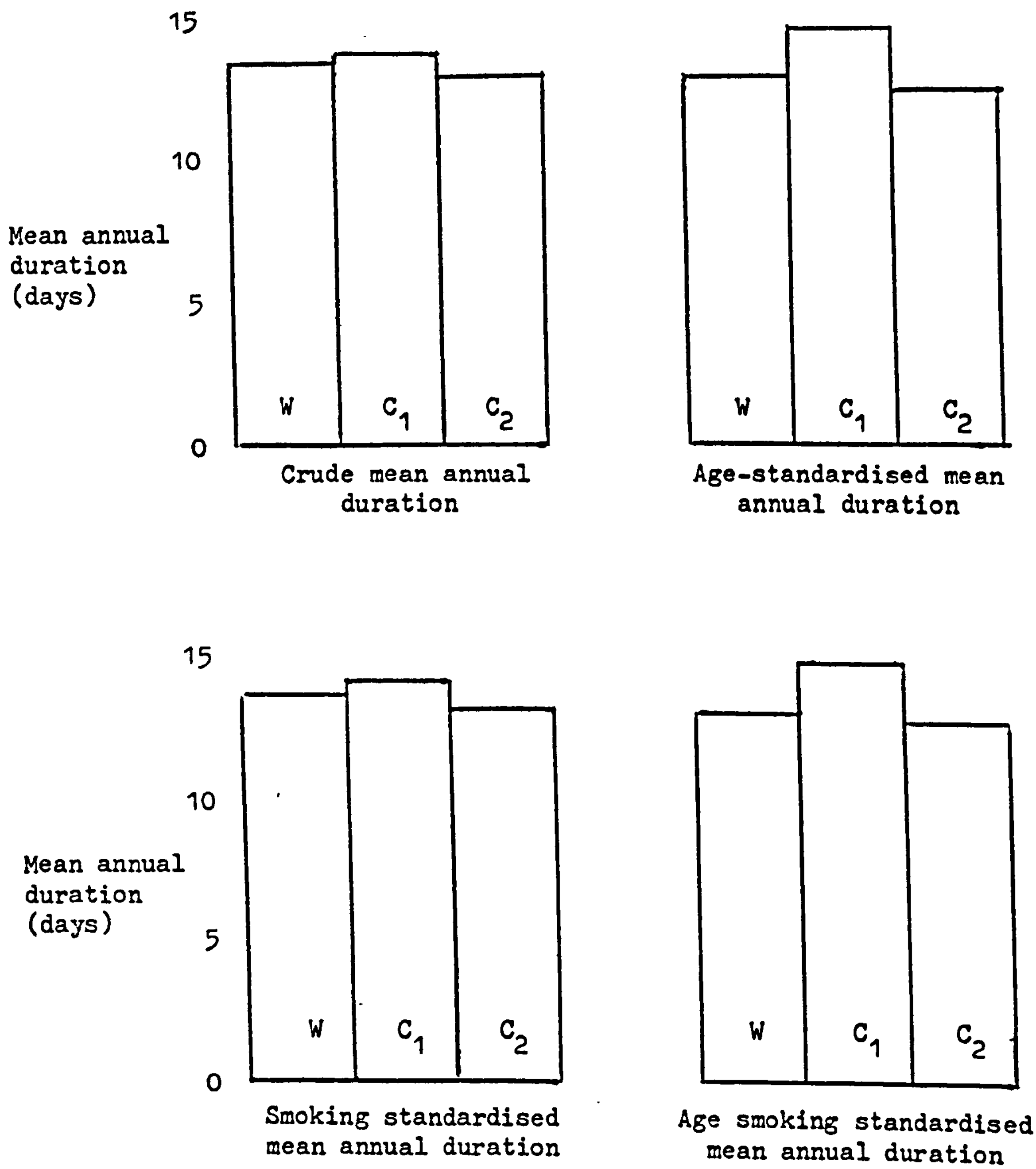


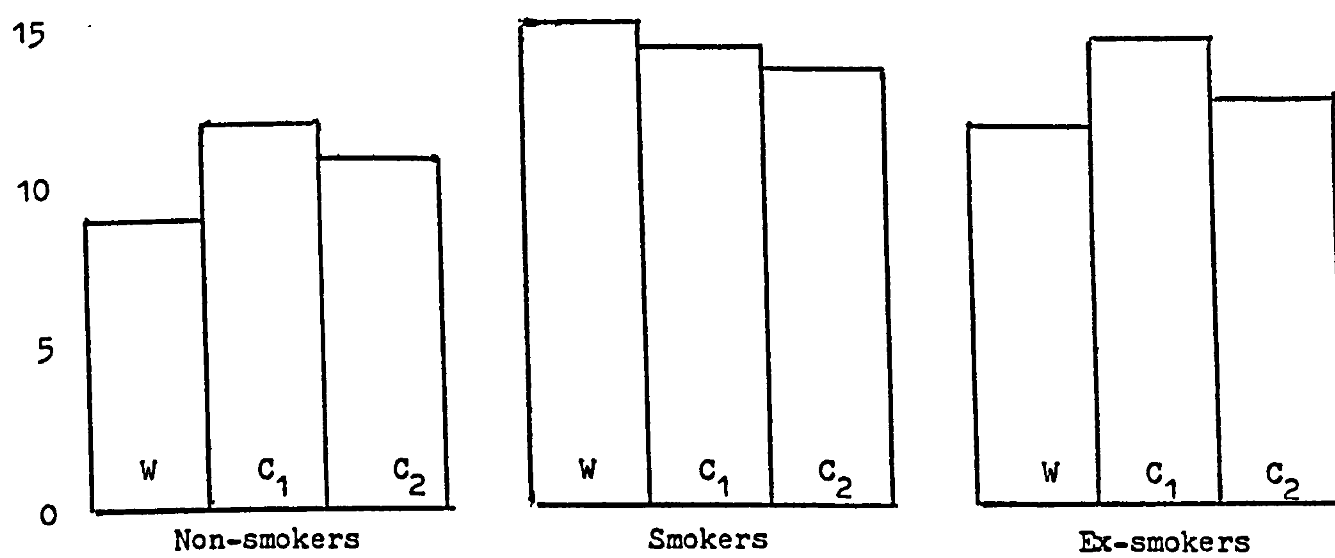
FIGURE A 62 Crude and standardised mean annual duration (days) of absence attributed to diseases other than respiratory in welders and controls in Dockyard Combined Population



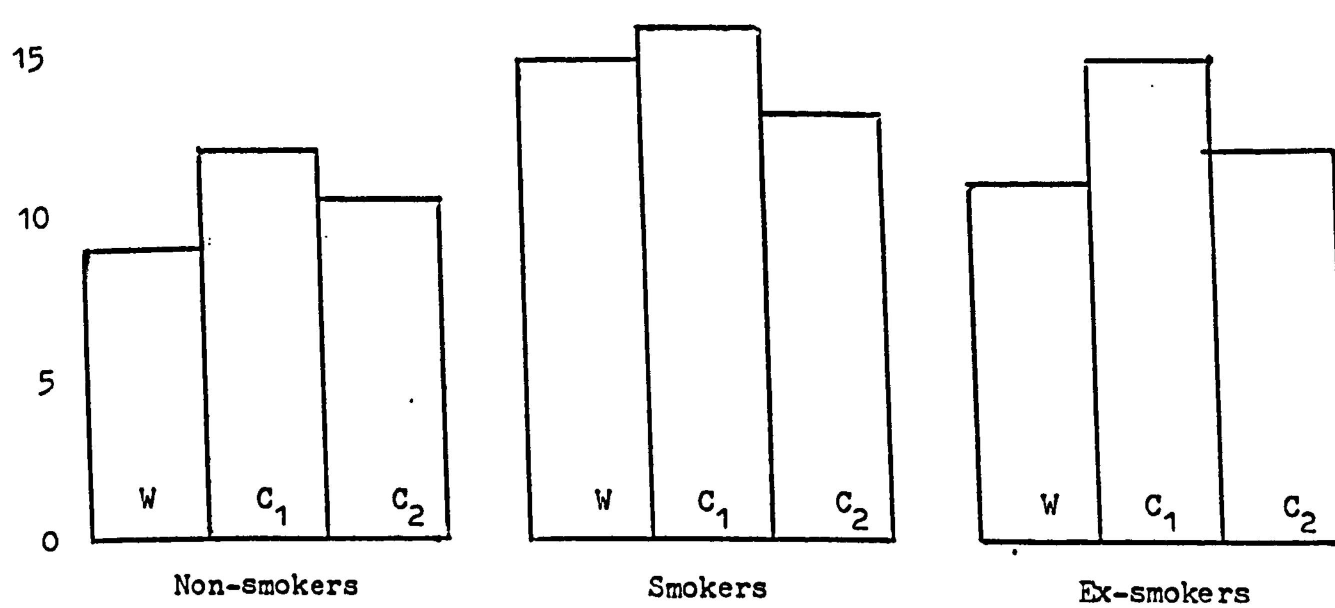
W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 63 Crude and age-standardised mean annual duration (days) of absence attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in Dockyard Combined Population

Crude mean annual duration



Age adjusted mean annual duration



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A 64 Mean length of spell (days) of absence attributed to diseases other than respiratory in welders and control groups in Dockyard Combined Population related to age

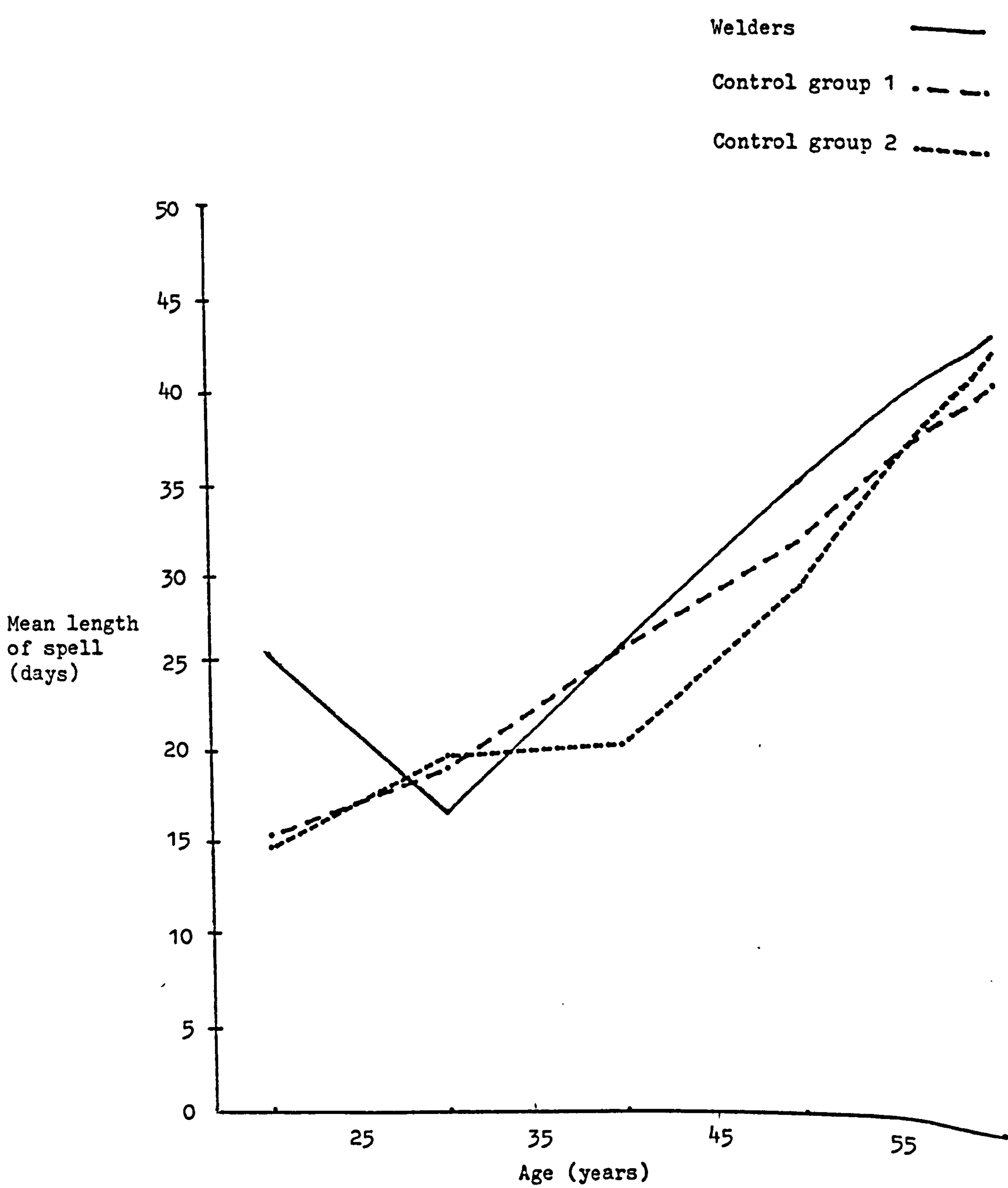
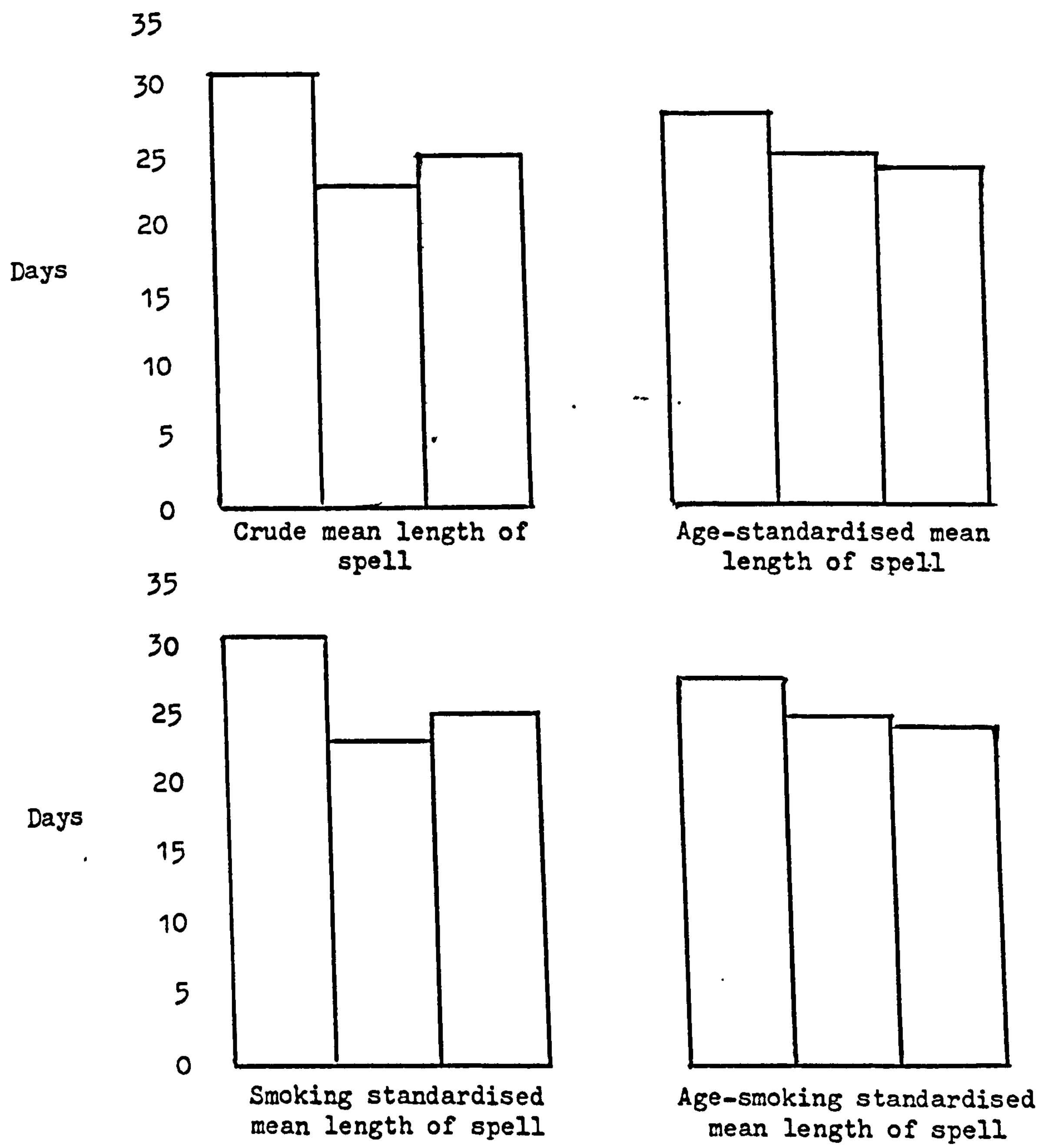
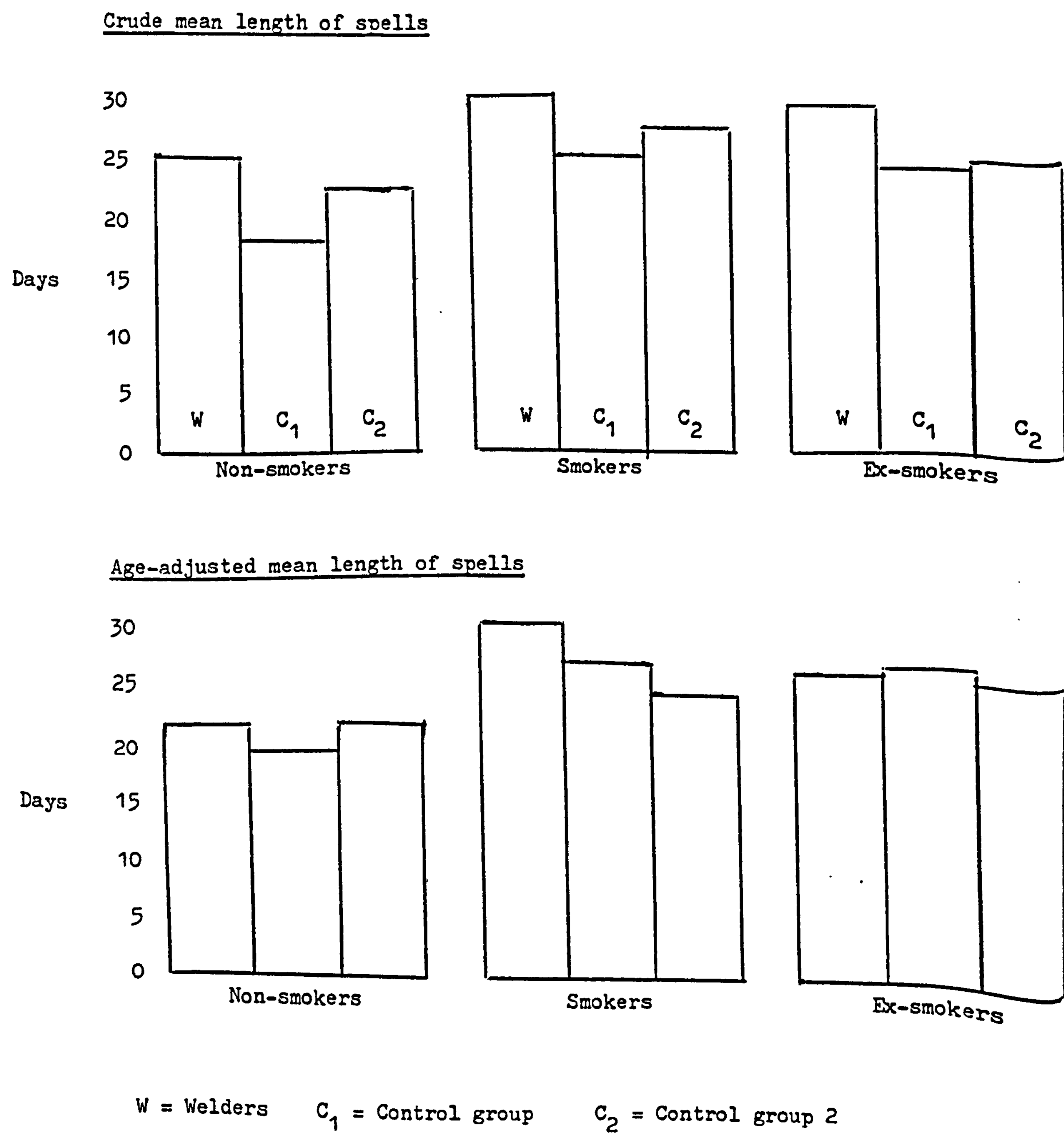


FIGURE A.65 Crude and standardised mean length of spells (days) of absence attributed to diseases other than respiratory in welders and control groups in Dockyard Combined Population



W = Welders C_1 = Control group 1 C_2 = Control group 2

FIGURE A66 Crude and age standardised mean length of spells (days) of absence attributed to diseases other than respiratory in non-smokers, smokers and ex-smokers in welders and control groups in the Dockyard Combined Population



APPENDIX 1

MEDICAL IN CONFIDENCE (when completed)

NAVAL DOCKYARDS WELDING FUME PROJECT

Please answer all questions carefully to the best of your ability either by writing in the boxes provided or by placing a tick in the appropriate box in some cases.

1. Have you ever smoked regularly? This means as much as one cigarette or small cigar a day or one large cigar a week or one ounce of tobacco a month for as long as a year. Yes ☐ No ☐

2. Do you smoke at present? Yes ☐ No ☐

3. If you have given up smoking

   a. Was this more than a month ago? Yes ☐ No ☐

   b. How old were you when you last give up? Age ☐

4. How old were you when you started smoking regularly? Age ☐

The next questions are about how much you now smoke or used to smoke if you have now given up.

5. How many manufactured cigarettes per day? ☐

6. How many ounces of hand rolled cigaretted tobacco per week? ☐

7. How many ounces of pipe tobacco per week? ☐

8. How many small cigars per day? ☐

9. How many large cigars per day? ☐

The last questions are about your journey to work.

1. How far do you travel to work? ☐ Miles

2. Do you walk to work? Yes ☐ No ☐

3. Do you travel by bus? Yes ☐ No ☐

4. Do you travel by train? Yes ☐ No ☐

5. Do you travel by car? Yes ☐ No ☐

6. Bus and train travellers only:-

   How many changes do you have to make on your journey to work. Enter number ☐

Seal the completed form in the enclosed envelope and hand it to your Technical Supervisor who will send it to the Medical Research Unit.

Ex-Yard

Telephone:
PLYMOUTH 53740
Extension 2795
or 3044

MEDICAL RESEARCH UNIT
No. 1 EAST AVENUE
H.M. NAVAL BASE
DEVONPORT
PL1 4RU

..................................19........

Dear Mr

The Medical Research Unit in the Dockyard has been asked to find out if welding fumes cause long term damage to health. As a starting point I am studying the amount of sickness absence members of various craft groups had in the last 5 years to see if those exposed to welding had more absence than others.

You were employed in the Dockyard during that period and I hope you will help me by answering the questions on the enclosed form. Your answers should apply to the time you were in the Dockyard.

The questions are about two subjects known to affect sickness absence. If I cannot take account of them in the study my conclusions may be wrong. The information will remain confidential to me. The form is identified only by a number and only I can tell who answered the questions.

Please put the answered questionnaire in the enclosed stamped addressed envelope and post it to me.

Many thanks
Yours sincerely

G H G McMILLAN
Medical Officer in Charge

Encl:

MEDICAL IN CONFIDENCE (when completed)

NAVAL DOCKYARDS WELDING FUME PROJECT

Please answer all the questions carefully to the best of your ability either by writing in the boxes provided or by placing a tick in the appropriate box in some cases.

1. Have you ever smoked regularly? This means as much as one cigarette or small cigar a day or one large cigar a week or one ounce of tobacco a month for as long as a year — Yes ☐ No ☐

2. Did you smoke when you were employed in the Dockyard? — Yes ☐ No ☐

3. If you have given up smoking

   a. Was this before you left employment in the Dockyard? — Yes ☐ No ☐

   b. How old were you when you last gave up? — Age ☐

4. How old were you when you started smoking regularly? — Age ☐

The next questions are about how much you smoked while in Dockyard employment or used to smoke if you gave up smoking before or during that employment

5. How many manufactured cigarettes per day? ☐

6. How many ounces of hand rolled cigarette tobacco per week? ☐

7. How many ounces of pipe tobacco per week? ☐

8. How many small cigars per day? ☐

9. How many large cigars per day? ☐

The last questions are about your journey to work. Tick the appropriate box.

10. How far did you travel to work? ☐ Miles

11. Did you walk to work? — Yes ☐ No ☐

12. Did you travel by bus? — Yes ☐ No ☐

13. Did you travel by train? — Yes ☐ No ☐

14. Did you travel by car? — Yes ☐ No ☐

    How many changes did you have to make on your journey to work. — Enter number ☐

MEDICAL IN CONFIDENCE WHEN COMPLETED

MRU WELDING FUME RETROSPECTIVE MORBIDITY SURVEY FORM 1(D) | W | O | 1 |

National Insurance Number

Surname

Initials

Date of birth

Occupation (Tick box)

- Welder
- Boilermaker
- Shipwright
- Electrical fitter ashore
- Painter
- Joiner

Date entered this occupation in Dockyard

Date entered apprenticeship in Dockyard

Date left this occupation in Dockyard

History of job change in Yard due to ill health. Y = Yes N = No

Invalided? Y = Yes N = No

If Yes Date of invaliding

Diagnosis ____________

Dead? Y = Yes N = No

If dead Date of death

Cause 1A ____________

1B ____________

II ____________

NHS Number

"Married" (M), "Singlw" (S)

Smoker Y = Yes N = No

Ex Smoker (6 months) Y = Yes N = No

Total days uncertificated sick absences

Number of spells of uncertificated sickness absence

MEDICAL IN CONFIDENCE (When completed)

MRU: WELDING FUME RETROSPECTIVE MORBIDITY SURVEY FORM 2 (D) | W | O | 2 | 1-3

National Insurance Number ☐☐☐☐☐☐☐☐☐ 12

Surname ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Initials ☐☐☐☐☐

Certified Sickness absence

	Diagnosis	Code	Start Date	Finish Date	
		30			
1		☐☐☐☐	/ /	/ /	46
2		☐☐☐☐	/ /	/ /	62
3		☐☐☐☐	/ /	/ /	78
4		☐☐☐☐	/ /	/ /	94
5		☐☐☐☐	/ /	/ /	110
6		☐☐☐☐	/ /	/ /	126
7		☐☐☐☐	/ /	/ /	142
8		☐☐☐☐	/ /	/ /	158
9		☐☐☐☐	/ /	/ /	174
10		☐☐☐☐	/ /	/ /	190
11		☐☐☐☐	/ /	/ /	206
12		☐☐☐☐	/ /	/ /	222
13		☐☐☐☐	/ /	/ /	238
14		☐☐☐☐	/ /	/ /	254
15		☐☐☐☐	/ /	/ /	270
16		☐☐☐☐	/ /	/ /	286

SECTION B

CASE CONTROL STUDY OF ACUTE CHANGES IN RESPIRATORY FUNCTION AND BLOOD LEVELS OF CERTAIN METALS IN WELDERS DURING STANDARDISED WELDING

Summary

Twenty-five welders with 6-25 years welding experience were matched by age, sex and smoking habit to 25 electrical fitters who worked in an area where welding was not normally done. Each man was clinically examined, had a full size film PA chest radiograph and performed a number of pulmonary function tests at this examination and then at the beginning and end of a shift. The gases and fumes in the breathing zone were sampled. Each welder worked for one day, making a total of 25 separate test days over a 5 week period. The welders worked in one site, using the same consumable and type of work piece.

There were no cases of siderosis and no significant difference in the overall prevalence of lung function abnormalities between welders and controls, although there were some differences in the pattern of abnormalities. No significant differences were found between lung function changes over the day in the group means of welders and controls. There was a significant positive correlation between the increase in residual volume and the fume concentrations in the breathing zones of the welders.

The methods and results are discussed and compared with previous investigations.

1. INTRODUCTION

This report describes the exposure to fumes and gases of twenty five male manual metal arc welders during a standardised welding task, the results of clinical and radiological examinations and their pulmonary function and blood levels of some of the metals (manganese, copper, zinc) contained in the welding fume, before and after exposure.

These physiological parameters are compared with those of unexposed controls matched for age, sex, race and smoking habit.

A random sample of welders was not studied as it would have been impossible to follow them on their normal work routine without introducing many uncontrollable compounding variables from day to day. This was exemplified during the study period when British warships damaged while protecting our fishing fleet in waters off Iceland were arriving in the Dockyard for unscheduled repairs. By reserving one normal working unit of welders for study we were able to plan the work and sampling procedures in advance and ensure that the measured exposure was that for a full working day.

No previously published work describes a similar study matching physiological and serial exposure parameters for welders. The idea was originated by the author and developed in close collaboration with a team of occupational hygienists from the Institute of Naval Medicine and the Welding Institute which measured exposure and air movement, and Dr R Pethybridge, Statistician at the Institute of Naval Medicine. The methods and results of sampling and analysis of fume and gases are described in detail by Evans et al (1979).

2. MATERIAL AND METHODS

2.1 The welding task

A planned production batch of dock blocks (figure B1) made of one inch thick mild steel plate (British Standard 4360) coated with a zinc-rich epoxy primer (65g Zn per m^2) was tack welded before the study. The blocks were transferred to the special welding area described below during the evenings and week-ends of the study period as required thus avoiding interruptions during the normal working day.

The welders each worked alone for one day on the standard task of completing welding the abutting surfaces of each block using manual metal arc welding. They were required to work at their normal piecework speed using 6 mm rutile electrodes (4 SWG Vodex Class E317) with current settings of 270-330 amps and arcing voltage of 20 volts. They wore their own protective clothing including head helmet (13 men) or hand held shield (12 men), whichever they normally used. None wore respiratory protection.

2.2 The work area

A semi-confined area of similar dimensions to those often found between decks in ships in refit was constructed ashore close to the Medical Research Unit by placing iron shelters ("igloos") to form tunnels within a metal box-like structure called a grid. The dock blocks were placed within the tunnels (figures B2-B5). This grid reduced variation of working conditions by the ambient weather and protected staff and equipment. Natural ventilation was measured on five days of the 25 day period using an SF6 tracer gas technique. The air change rate varied from 5-11 changes per hour and this was considered to be representative of the 25 days.

2.3 Subjects and controls

Twenty five welders paired with 25 controls were studied. All potential welders and controls underwent a preliminary medical examination including occupational history, respiratory symptoms questionnaire, clinical examination, full size PA chest radiograph and respiratory function tests (FEV_1, FVC, RV, TLC, TF, FET, MEF_{50}, MEF_{25}). Men were rejected only if they could not work in the test work area, could not perform lung function tests because of ineptitude or active respiratory tract infection or when controls were not available.

The preliminary examination of potential subjects and controls also served to acquaint them with the staff and apparatus, and to ensure that the battery of tests could be administered satisfactorily in the time available during the shift study period.

All twenty seven welders in one work unit agreed to participate but six were rejected. One had severe osteoarthritis of the knees and was restricted to bench work, one was on night shift, two were on annual leave and controls could not be found for two. Four welders were chosen at random from another work group in the Yard to make up the study group of twenty five.

The final group of twenty five welders comprised nineteen smokers, four ex-smokers and two non-smokers. The definitions used were:-

- Smoker - currently smokes and has done for at least one year.
- Ex-smoker - stopped smoking for at least 3 years having smoked for at least a year.
- Non-smoker - has never smoked for as long as a year.

All potentially suitable controls, to match each welder by race, sex, age and smoking habit, in a population of 217 electrical fitters working in a welding free environment were approached by the same methods used for the welders. Fifty of the 63 initially selected because of their matching potential agreed and were available to participate and final matching was done after the preliminary medical examination. Two potential controls were rejected. One had coryza and the other, an asthmatic since childhood, was unhappy to repeat the respiratory function tests. Significant and previously undetected abnormalities were found in 14 other men who were included in the control pool but were referred to their general practitioners.

For the preliminary examination each welder and all his potential controls were grouped together and five such groups were examined every 3 days, appointments having been allocated randomly, during normal working hours. Those rejected were removed from the original group and the electrical fitter listed next to each welder in the final group was selected as the paired control.

To avoid observer bias, the author and laboratory staff were kept unaware of the man's occupation until after the respiratory function tests had been completed and the medical history had been taken. On arrival the subjects were interviewed by a clerk who recorded personal details and an occupational history from school leaving age. The doctor questioned each man using the MRC Respiratory Symptoms Questionnaire with minor amendments and additional questions on exposure to asbestos. Questions relating to occupation were asked last. Clinical examination was confined to the respiratory and cardiovascular systems unless the history suggested that further examination was required.

2.4 Respiratory function tests

Respiratory function was tested by the author's scientific staff led by Dr J Heath. The sequence of tests was kept constant for all subjects and controls and during both the preliminary and shift study. All tests were conducted with the subject seated and at the same times daily during the shift study to negate effects of diurnal variation. Operators were constant to each test throughout.

FEV_1 and FVC were measured with the digital display model of the McDermott dry spirometer and corrected for temperature and pressure. The mean values of three satisfactory blows following two practice blows were taken at the preliminary examination but during the shift study the best of three blows was selected by the operator. The timing mechanism of the spirometer was checked each morning using a standard calibration weight and orifice. FET was measured by timing with a stopwatch the period during which the spirometer bellows was seen to move. The mean of three satisfactory blows was taken and, since the distribution of FET has been found to be markedly skew, a square-root transformation was used for statistical analysis.

Time and volume outputs from the dry spirometer were recorded onto magnetic tape and later analysed using a Hewlett-Packard 9830 programmable calculator to give a flow volume curve, MEF_{50} and MEF_{25}, which were corrected for room temperature. The values obtained from the best of three blows were used for analysis.

Transfer factor was measured with a Mk IV Morgan Resparameter. In subjects with a FEV_1 greater than 2.0 L the alveolar volumes measured simultaneously with transfer factor were used for the calculation of lung volumes, since, in the absence of obstructive disease, this method gives the same result as and is more reproducible than the standard rebreathing method (Teculescu, 1974). In subjects with a FEV_1 less than 2.0 L the rebreathing method was used for measuring lung volumes at the main clinical examination, but the more reproducible and quicker single breath method was used in the comparison of lung function before and after shift.

2.5 Blood samples and analysis

During the shift study a 15 ml of venous blood was taken at 0745 and 1530 to estimate changes in metal concentration over the day and differences between welders and controls. Analysis was undertaken by Mr T Sharpe, Institute of Naval Medicine.

2.6 Sampling and analysis of fumes and gases

The occupational hygienists devised and applied a sampling procedure to:-

a. estimate the total breathing zone concentrations of total and respirable fume and principal constituents (iron, manganese, zinc and copper) expressed as time weighted average (8 hour), the latter to allow comparison with published Threshold Limit Values.

b. estimate the breathing zone concentration of the gases NO and NO_2 separately or together, plus CO and O_3, and express the results as time weighted averages.

c. obtain for five welders a continuous record of breathing zone concentrations of these gases.

d. obtain a continuous record of events related to exposure, individual characteristics and consumption of material.

Details are given in Evans et al (1979) from which the line diagram of the sampling equipment (figure B6) and analysis results quoted are taken. Long term (hours) samples of fume were collected on one lapel close to the breathing zone using Casella personal samplers in the manner indicated by the BSI Draft Standard (1977). The output from the paper tape monitor was integrated to give the area under the curve and used as a simple measure of total fume in arbitrary units.

Spot concentrations of oxides of nitrogen, nitrogen dioxide, ozone and carbon monoxide were taken using appropriate Draeger detection tubes. On average ten tubes were used per half shift for each welder for NO_x, CO and O_3. Time weighted averages for the working time and 8 hour exposure were calculated from the formula

$$C_W = \frac{C_1 + C_2 + \cdots\cdots\cdots + C_n}{n}$$

where C_W is the calculated average concentration over the time and C_1, C_2 etc are the successive measurements for the same gas during the working period.

Air from the breathing zone was drawn down a PTFE sampling line by a personal sampler at 2-4 litres per minute and the gas sampled drawn off this line. A continuous record of breathing zone concentrations of the gases was obtained using a chemiluminescent gas analyser for NO and NO_x, an Ecolyser for CO and a portable ozone analyser. Some of the equipment is illustrated in figures B7 and B8.

2.7 Statistical methods

The statistical analysis of all the results obtained was designed in consultation with Dr R Pethybridge and Dr J Heath. The small number of non-smokers and ex-smokers restricted the application of tests of statistical significance. Standard Student's T test and Chi^2 test were used whenever possible and appropriate but in some situations non-parametric methods were necessary (Sign test, Wilcoxon's two sample ranking test).

Lung function indices (FEV_1, FVC, FEV%, RV, TLC, TL^1) were standardised for height using the regression equations of Cotes (1968) for smokers and non-smokers. An equation derived by Dr Heath from a series of lung function results in a section of the Dockyard employees with occasional exposure to asbestos which had been studied between 1966 and 1975, was used to standardise for age for smoking and non/ex-smokers. This group comprised 70 smokers and 37 non and ex-smokers who had remained in that smoking category during the study period 1966-75. The mean change in lung function/year under study was taken to be the regression on age assuming that change with age was virtually linear.

3. RESULTS

3.1 Data obtained at the preliminary examination

The welders' time in that occupation ranged from 6 to 43 years (mean 25.6 years) with nineteen having more than 20 years experience. Twenty three had used manual metal arc welding (MMA) almost exclusively and two had used metal inert gas welding (MIG) more than MMA (table B1).

There were no significant differences between the mean age, height and weight of the welders and controls (table B2) nor in the number of each group with abnormal respiratory symptoms and signs on clinical examination (tables B3 and B4). Nine welders (six smokers) and eight controls (seven smokers) reported one or more symptoms. They were of the same mean age. Chronic bronchitis (MRC definition) was diagnosed in five welders and two controls but only three welders in contrast to nine controls had been absent for over a week with a diagnosis of "bronchitis". Five welders and three controls had abnormal signs.

Although nine welders and four controls had radiographic abnormalities of parenchymal and/or pleura there was no evidence of siderosis (table B5). Eight welders and two controls had pleural abnormalities which could be related to previous exposure to asbestos, but of these, two welders and both controls had had pleurisy which could explain the abnormalities. One welder had asbestos related parenchymal fibrosis (table B5). Overall mean reported potential exposure to asbestos was similar in both groups (W = 6.6 years, C = 6.8 years), but the distribution differed, more welders being exposed than controls.

The individual assessments of respiratory function at the preliminary examination were used to identify abnormal patterns on the basis of FEV_1, below 75% of predicted normal values and/or FEV_1/FVC% below 90% predicted normal. The remaining indices were used to classify abnormalities by degrees. There was no statistically significant difference between the overall prevalence of abnormal patterns (13 welders and 14 controls) but the degree of obstruction was greater in the welders and of restriction in the controls. Most of those with abnormalities were smokers (table B6). The group means for each index which could be standardised did not differ significantly between the groups of welders and controls after standardisation for age and height with the exception of the difference between FEV_1 between smokers and all non and ex-smokers (table B7). $\sqrt{FET}$, MEF_{25} and MEF_{50} could not be standardised as data did not exist for our standard population. There were slight differences in the crude MEF_{50} and MEF_{25} for non and ex-smokers in welders and controls (table B8). These may have disappeared if standardisation had been possible. There were no significant differences in standardised group means of LFT indices of welders with less than and more than 25 years exposure to welding (table B9). The proportion of smokers in each group was the same.

3.2 Data obtained by occupational hygienists during performance of the welding task and exposure to fumes and gases. (Evans et al, 1979)

Welders worked on the standard task for periods varying between 176 and 252 minutes with an average of 214 minutes per day. Actual welding time (arcing time) ranged between 75 and 150 minutes, average 111 minutes, some 52% of the working time. Individual arcing periods ranged from less than 30 seconds to more than 2 minutes. The number of electrodes used ranged from 43 to 82 with an average of 61.

The principal elements in the fume were iron, manganese, zinc and copper. The total concentrations of fume for the working time ranged from 2.5 to 69.4 mg/m^3 with a group mean of 26.7 mg/m^3 (table B10). When expressed as time weighted average concentration for 8 hours (table B11) the group mean was 11.4 mg/m^3, 19 of the 25 values exceeding the TLV of 5 mg/m^3. Respirable samples gave a mean value of 71% of the total samples. There was a wide variation in daily exposure patterns.

The average working time concentrations as detected by Draeger tubes for CO was 6.2 ppm (range 0-19.1 ppm) and for NO and NO_2 was 0.7 ppm (range 0-2.2 ppm). Nitrogen dioxide and ozone were detectable only in questionable trace quantities. Exposure to these gases was in a series of short term peaks corresponding to the arcing periods. A typical section of recorded output from automatic analysers for NO, NO_x and CO is shown in figure B9. As mentioned, exposure to fume varied between the men. The same was true of exposure to gases. Posture was considered to be the major contributory factor, some welders worked continuously in the plume, others occasionally entered it or always stayed clear.

3.3 Respiratory function data obtained from welders undertaking the task and their controls

The differences between respiratory function indices (standardised for temperature and pressure) of welders and controls over the work period are summarised in table B12. There are no significant differences between the group means of welders and controls, nor of smokers and non-smokers. The respiratory function results were correlated with the levels of fumes and gases to which the welders were exposed (table B13, figure B10). There is a positive correlation (significant at the 5% level) between the change in residual volume and total fume, respirable fume, iron oxide fume and NO_x, the change being negative at the lower concentrations and positive at the higher values. Figure B10 also demonstrates the wide range of exposures experienced even though the men were engaged in ostensibly similar tasks.

3.4 Concentrations of metals in blood of welders and controls

The measured concentrations of manganese, copper and zinc in blood samples taken from welders and controls are shown in table B14. There are no statistically significant differences between within group morning and afternoon levels for any of the metals, nor between contemporary levels for copper and zinc between welders and controls. Four manganese welders have significantly (at 5% level, Wilcoxon's sign test) higher values compared to matched controls, the means being 3.1 and 2.4 ug/ml whole blood respectively. All levels were within accepted normal limits (Whitlock et al, 1966., Emara et al, 1971., Chandra et al, 1974).

4. DISCUSSION

Comparison of the clinical findings on 25 welders with those of studies involving larger groups must be made with caution as the latter are less liable to statistical error.

While nine of the welders and eight controls had respiratory symptoms, in a similarly controlled study of 25 welders Kleinfeld et al (1969) found that only two welders and two controls had symptoms; their smoking habits are not reported. A similar low prevalence of symptoms was detected in a larger study by Peters et al (1973).

The findings in the reported study agree with those of Fogh et al (1969) studying 156 welders. Unfortunately the small numbers prevent meaningful correlation between symptoms and smoking habit. Fogh found that the proportion of men showing symptoms increased with increasing use of tobacco, welders being more affected than controls.

In contrast Hunnicutt et al (1964) and Barhad et al (1975), found significant differences between the prevalence of respiratory symptoms in welders and controls. Hunnicutt's study involved 100 welders excluding all potential subjects and controls with significant abnormalities on the chest radiograph, with asthma, past exposure to irritant gases or fumes and those with known cardiovascular disease. Respiratory symptoms were found in 68% welders and 28% controls. The population studies by Barhad and colleagues was younger than Hunnicutt's and a larger proportion smoked. They found that 20% of welders had dyspnoea and 16% wheezing: chronic bronchitis was diagnosed in 20%. There were no cases of siderosis. The experiences of other investigators are summarized in table B15 which shows the considerable variation in prevalence between populations.

While there was no difference in the prevalence of abnormal patterns of respiratory functions between welders and controls, the degree of obstruction was greater in welders and of restriction in the controls. This may be of clinical significance. As more welders had been exposed to asbestos the opposite might have been expected. Peters et al (1973) found a similar dichotomy but their controls had a greater asbestos exposure than the welders.

Kierst et al (1964) reported reduced vital capacity in a third of his 173 welders. Barhad et al (1975) found a ventilatory defect (mostly of the restrictive type) in 20% of 125 welders. Hunnicutt et al (1964) found that smoking and welding almost doubled the prevalence of abnormal lung function. Abnormal results (mainly obstructive) were found in 45% welders who smoked compared with 34% non-smoking welders and 25% controls who smoked. Pilat et al (1963), Fogh et al (1969) and Kleinfeld et al (1969) found no significant differences in lung function patterns of their study groups, but in Fogh's welders there was tendency to reduced FEV_1 with increasing use of tobacco.

Kierst et al (1964) reported a trend towards reduced FEV_1 with increasing length of exposure. We did not confirm this when we compared the standardised group means of welders with less than 25 years and 25 years and more exposure (table 6).

In this shift study neither welders nor controls showed any significant differences in standardized group mean indices of respiratory function over the study shift. There was, however, considerable individual variation. This may be due to existing lung disease, individual susceptibility or variation in technique, especially posture, which Evans et al (1979) have demonstrated is the main factor influencing exposure to fume and gases.

The physiological data were correlated with the levels of fumes and gases to which the welders were exposed (Evans et al, 1979). The positive correlation (significant at the 5% level) between the change in residual volume and total and respirable fume, iron oxide fume and NO_x may be important. MEF_{50} and FET results suggest that the increase in residual volume with increasing exposure is related to obstructive changes in the small airways. Discrimination between the effects of the different fume constituents is not possible as their concentration levels were closely correlated. Nor can we offer any biological explanation why the change in RV relative to the controls was negative at low fume concentrations changing to positive at further values.

The blood metal levels suggest that no significant amounts of the examined metals are absorbed. However, these are not very good indicators. For example manganese is thought to have no cumulative effect and is rapidly excreted from the body (Emara et al, 1971). Concentrations of manganese in whole blood from workers in a manganese alloy plant did not increase with time of employment. In general there is no consistent pattern of serum manganese concentration in patients with intoxication (Whitlock et al, 1966). There is agreement that estimations of serum manganese has no significance in detecting manganese poisoning (Chandra et al, 1974).

Several workers are currently studying the fate and effects of welding pollutants in the body. It is important that they are supplied with accurate specification of welders' exposure if they are to produce meaningful results. Beil and Ulmer (1976) have studied the effect of exposure to constant concentrations of 5 ppm and less of nitrogen dioxide for periods of 2 and 14 hours on the airway resistance (Rt) of healthy human subjects. This does not reflect the dockyard welders' exposure to oxides of nitrogen, as only trace quantities of nitrogen dioxide were present, the concentrations were not constant, and the exposure periods more than

2 and much less than 14 hours (Evans et al, 1979). Despite these reservations their findings are of interest, as they confirm the suspicion that these low concentrations do affect lung function and that individual susceptibility may be an important factor. There was no dose-response relationship, but the changes in Rt values during exposure showed an initial peak then a decreasing tendency until the second hour concluding with a new, more pronounced increase which was correlated with the further time of exposure. There was significant individual susceptibility shown by the correlation between the individual amount of the increase of Rt during exposure and the increase in Rt after inhalation of acetylcholine (a measure of bronchial susceptibility to broncho-constricting irritants).

If this phenomenon also occurs with nitric oxide it may be surmised that greater increase in Rt will be produced by the higher concentrations of NO and NO_2 present during arcing and perhaps also in these welders with pre-existing obstructive airways disease.

As far as the evidence can be collated it supports the opinion that MMA welding may have a deleterious effect on the respiratory system, but this is unlikely to be dramatic and may only be manifested in those with higher exposure due to poor ventilation in the working environment or to their technique and those who are exposed to other irritant pollutants, especially tobacco smoke. As the fumes and gases contain a mixture of bronchial and alveolar irritants it is not unreasonable to expect a mixed pathology with obstructive disease predominating in the smokers.

The evidence is far from conclusive and at this stage it would be irresponsible to state that the process is dangerous - unless commonsense safety precautions are disregarded. It would appear reasonable to lay greater stress on welder education. They must be taught and exhorted to protect themselves by using fume extraction equipment and adequate ventilation and ensuring that they avoid the fume plume. Those with obstructive airways disease should be identified by pre-employment examination (see Section G conclusions for suggested schedule) and employed only where the fume and gas concentrations can be kept well below the TLV. This work can be done by ancillary staff using a standard questionnaire and Vitalograph. Comprehensive medical examinations of all welders cannot be justified in this context. The welders should be made aware of the increased risks of smoking.

5. CONCLUSIONS

1. It is possible to concurrently measure welders' lung function and exposure to pollutants over a working shift.

2. There were no biologically significant differences between welders and controls in the questionnaire, X-ray, lung function findings nor levels of metals in the blood.

3. There was no difference in lung function in welders with greater or less than the mean length of exposure of 25 years.

4. There were no significant acute changes in group mean lung function findings in welders or controls, whether smokers or non-smokers, over the period of the shift.

5. There was a positive correlation between increase in residual volume over the shift and the level of pollutants to which the welder was exposed but the significance of this is not clear.

REFERENCES

AHLMARK, A. and LONNEBERG, B. (1953)
A clinical examination of workers with more than 5 years continuous welding experience.
Nord. Hyg. Tidskr. 34,238.

BARHAD, B., TECULESCU, D and CRACIUM, O. (1975)
Respiratory symptoms, chronic bronchitis and ventilatory function in shipyard welders.
Int. Arch. Occup. Environ. Hlth. 36,137.

BEIL, M. and ULMER, W.T. (1976)
Effect of nitrogen dioxide in workroom concentrations on respiratory mechanics and bronchial susceptibility to acetylcholine in normal persons.
Int. Arch. Occup. Environ. Hlth. 38,31.

CHANDRA, S.V., SETH, P.K. and MANKESHWAR, J.K. (1974)
Manganese poisoning: clinical and biochemical observations.
Environ. Res. 7,374.

COTES, J.E. (1968)
Lung function: Assessment and Application in Medicine. 2nd Edn. 604
Blackwell, London.

EMARA, A.M., EL-GHAWABI, S.H., MADKOUR, O.I. and EL-SAMRA, G.H. (1971)
Chronic manganese poisoning in the dry battery industry.
Brit. J. Industr. Med. 28,78.

EVANS, M.J., INGLE, J., MOLYNEUX, M.K., SHARP, G.T.H. and SWAIN, J. (1979).
An occupational hygiene study of a controlled welding task using a general purpose rutile electrode.
Ann. Occup. Hyg. 21,341.

FOGH, A., FROST, J. and GEORG, J. (1969)
Respiratory symptoms and pulmonary function in welders.
Ann. Occup. Hyg. 12,4,213.

FRIEDE, E and RACHOW, D.O. (1961)
Symptomatic pulmonary disease in arc welders.
Ann. Intern. Med. 54,121.

HUNNICUTT, T.N., CRACOVANER, D.J. and MYLES, J.T. (1964)
Spirometric measurement in welders.
Arch. Environ. Hlth., 8,661.

KIERST, W., USELIS, J., CRACZYK, M. and KRYNICKI, A. (1964)
Pulmonary changes in shipyard arc welders.
Bull. Inst. Mar. Med. Gdansk 15,149.

KLEINFELD, M., MESSITE, J., KOOYMAN, O. and SHAPIRO,J. (1969)
Welders' Siderosis.
Arch. Environ. Hlth. 19,70.

PETERS, J.M., MURPHY, R.L. FERRIS, B.G., BURGESS, W.A. RANADIVE, M.V. and PERDERGRASS, H.P. (1973).
Pulmonary function in shipyard welders.
Arch. Environ. Hlth, 26,28.

PILAT, L., LILIS, R. and CRACIUM, O. (1963).
Med-Interna (Buc) 15,213. Cited by Stanescu (1967).

SCHULER, P., MATURANA, V., CRUZ, E., GUIJON, C., VASQUEZ, A., VALENZUELA, A. and SILVA, R. (1962).
Arc welders' pulmonary siderosis.
J. Occup. Med. 4,353.

TECULESCU, D.B. (1974).
Single breath total lung capacity determinations in patients with non-obstructive lung disease.
Bull. Physio-Path. Resp. 10,147.

WHITLOCK, C.M., AMUSO, S.J. and BITTENBENDER, J.B. (1966).
Chronic neurological disease in two manganese steel workers.
Am. Ind. Hyg. Assocn. J. 27,454.

TABLE B1 Processes used by welders during their working lives

Process	Only process	Main process	Occasional use
Manual metal arc	7	16	2
Tungsten inert gas			5
Metal inert gas		2	13
Gas (oxyacetylene)			2

TABLE B2 Mean age, height and weight of welders and controls

Parameter	Welders		Controls	
	Mean	SD	Mean	SD
Age (years)	44.2	10	44.0	10
Height (cms)	172.2	6.8	173.6	6.9
Weight (Kg)	74.2	12.5	73.8	9.7

TABLE B3 Respiratory symptoms reported by welders and controls

Symptoms	Welders			Controls		
	All	Smokers	Ex & Non-smokers	All	Smokers	Ex & Non-smokers
Dry cough	1		1	2	2	
Morning phlegm, no cough	1		1			
Cough and phlegm only	2	1	1	1	1	
Dyspnoea grade 2	2	2		3	2	1
Phlegm and dyspnoea				1	1	
Cough, phlegm and dyspnoea	3	3		1	1	
Totals	9	6	3	8	7	1
"Chronic bronchitis"	5	4	1	2	2	-

Welders compared with controls $X^2 = 0.089$. Comparisons with smoking habit, $g = 1.672$. Neither is significant.

TABLE B4 Abnormal respiratory clinical signs

Signs	Welders			Controls		
	All	Smokers	Non & Ex-smokers	All	Smokers	Non & Ex-smokers
Persistent rales	3	1	2	1	1	-
Persistent rhonchii	2	2	-	2	2	-
Total	5	3	2	3	3	-

Difference in prevalence between welders and controls is not significant, $\chi^2 = 0.601$.

TABLE B5 Radiographic abnormalities in welders and controls

Abnormality	Welders	Controls
Parenchymal fibrosis (asbestos related)	1	
Bilateral hyaline pleural plaques	4	
Diffuse pleural thickening	3*	2**
Old healed tuberculosis	1	2
Cardiovascular abnormalities		2
Total excluding cardiovascular	9	4

*Past history of pleurisy in one case: all had asbestos exposure.
** Past history of pleurisy in both cases, neither had asbestos exposure.
Difference in prevalence is not significant χ^2 being 2.651.

TABLE B6 Abnormal lung function patterns at preliminary examinations

Abnormality	Welders			Controls		
	All	Smokers	Non & Ex-smokers	All	Smokers	Non & Ex-smokers
Mild obstructive	2		2	7	6	1
Moderate obstructive	6	5	1	2	2	
Severe obstructive	2	2		2	2	
Slight restrictive	2	2		1		1
Moderate restrictive				2	2	
Reduced transfer factor only	1	1				
Total	13	10	3	14	12	2

The difference in prevalence between welders and controls is not significant $\chi^2 = 0.081$, nor is that between those of different smoking habit, g = 1.743.

TABLE B7 Mean age and height standardised lung function test results at preliminary examination

Lung function test	Smoking habit	Welders Mean	Welders SD	Controls Mean	Controls SD
FEV_1 (litres)	Smokers	3.34	0.45	3.31	0.69
	Non & ex-smokers	3.63	0.27	3.92	0.65
	All	3.41	0.42	3.46	0.72
FVC (litres)	Smokers	4.62	0.34	4.63	0.66
	Non & ex-smokers	4.93	0.55	4.92	0.80
	All	4.69	0.41	4.70	0.69
$\frac{FEV_1}{FVC}$ %	Smokers	72.6	10.0	71.7	10.8
	Non & ex-smokers	74.5	10.4	79.7	6.6
	All	73.1	9.9	73.6	3.6
RV (litres)	Smokers	2.09	0.37	2.19	0.50
	Non & ex-smokers	1.76	0.38	2.19	0.30
	All	2.01	0.39	2.19	0.45
TLC (litres)	Smokers	6.73	0.45	6.82	0.88
	Non & ex-smokers	6.71	0.71	7.16	0.60
	All	6.73	0.51	6.90	0.82
Transfer factor ($mmol^{-1}$ Kpa^{-1} min^{-1})	Smokers	9.16	1.50	9.37	1.78
	Non & ex-smokers	11.49	2.26	11.09	1.14
	All	9.72	1.94	9.78	1.79

TABLE B8 Mean unstandardised $\sqrt{FET}$, MEF_{25} and MEF_{50} results at preliminary examination

Lung function test	Smoking habit	Welders Mean	Welders SD	Controls Mean	Controls SD
$\sqrt{FET}$	Smokers	3.27	0.60	3.20	0.60
	Non & ex-smokers	2.87	0.40	2.87	0.59
	All	3.17	0.58	3.12	0.60
MEF_{25} (litres Sec^{-1})	Smokers	1.062	0.638	1.048	0.646
	Non & ex-smokers	1.123	0.524	1.538	1.056
	All	1.080	0.600	1.170	0.770
MEF_{50} (litres Sec^{-1})	Smokers	3.567	1.879	3.622	2.050
	Non & ex-smokers	3.587	1.386	4.493	2.171
	All	3.572	1.860	3.840	2.069

TABLE B9 Comparison of group mean lung function indices of welders with different length of exposure to welding

Lung function	Less than 25 years, n = 10		25 years and more, n = 15	
	Mean	SD	Mean	SD
* FEV_1 (litres)	3.43	0.36	3.40	0.48
* FVC (litres)	4.82	0.50	4.61	0.33
* FEV/FVC%	71.5	7.2	74.1	11.5
* RV (litres)	2.09	0.39	1.96	0.40
* TLC (litres)	6.81	0.55	6.67	0.49
* RV/TLC%	30.6	4.9	29.1	4.6
* Transfer factor	9.94	2.20	9.57	1.82
$\sqrt{FET}$	2.91	0.64	3.35	0.48
MEF_{50} (litres Sec^{-1})	4.28	1.70	3.15	1.67
MEF_{25} (litres Sec^{-1})	1.34	0.62	0.92	0.55

* Age and height standardised

TABLE B10 Air sampling results - 8 hour time weighted average concentrations (mg/m^3)

Day	Total Fume	Resp. Fume	Total Cu	Total Fe_2O_3	Total Mn	Total ZnO	$\frac{\text{Resp. Fume}}{\text{Total Fume}} \times 100\%$	$\frac{\text{Total Metal}}{\text{Total Fume}} \times 100\%$
1	8.8	8.7	0.03	1.6	<0.5	0.9	99	33
2	3.9	3.5	<0.02	1.3	<0.5	1.0	90	64
3	7.3	3.4	<0.02	2.3	<0.5	1.8	47	62
4	17.0	12.4	<0.02	4.7	0.8	3.4	73	52
5	23.1	9.7	0.02	5.9	1.1	5.9	42	56
6	6.7	2.2	0.02	1.9	<0.5	1.9	33	61
7	5.2	2.7	<0.02	2.5	<0.5	3.9	52	131
8	4.8	7.4	<0.02	1.2	<0.5	1.4	154	58
9	2.5	0.8	<0.02	0.6	<0.5	0.6	32	52
10	5.8	3.9	<0.02	1.7	<0.5	1.6	67	62
11	4.2	2.4	0.02	2.0	<0.5	2.0	57	102
12	27.9	22.8	0.03	7.7	1.3	7.6	82	59
13	1.0	2.0	<0.02	0.5	<0.5	0.5	200	100
14	6.9	8.1	<0.02	2.5	0.5	3.1	117	88
15	20.5	15.6	0.02	5.8	1.0	6.3	76	63
16	5.3	2.2	<0.02	1.6	<0.5	1.5	42	64
17	25.2	6.8	0.03	7.2	1.0	5.2	27	53
18	19.1	12.5	0.02	4.8	0.7	4.2	65	51
19	8.5	1.6	0.02	2.4	<0.5	2.1	19	58
20	6.0	2.3	0.02	0.8	<0.5	0.8	38	27
21	15.0	8.6	0.04	2.0	<0.5	2.5	57	32
22	25.8	15.3	0.07	7.1	1.2	6.6	59	58
23	14.6	14.1	<0.02	3.9	<0.5	4.5	97	62
24	9.2	7.9	<0.02	1.9	<0.5	2.4	86	50
25	11.0	5.8	<0.02	1.3	<0.5	2.4	53	36
Mean	11.4	7.3		3.0		3.0		
S.D.	7.9	5.5		2.2		2.0		
Range	1.0 to 27.9	1.6 to 22.8		0.5 to 7.7		0.5 to 7.6		

<values are to appropriate TLVs

TABLE B11 Air sampling results. Average concentrations. Over working time

	Total fume mg/m^3	Resp. fume mg/m^3	Total Cu mg/m^3	Total FE_2O_3 mg/m^3	Casella sampler Total Mn mg/m^3	Total ZnO mg/m^3	$\frac{\text{Resp. fume}}{\text{Total fume}} \times 100$	$\frac{\text{Total metal}}{\text{Total fume}} \times 100$	Draeger tube Average concn. of CO over working time (ppm)	Average concn. of NO_x over working time (ppm)
Mean	26.7	17.1	0.04	7.3	1.2	6.9	71.1	61.5	6.23	0.65
S.D.	18.7	12.8	0.03	5.2	0.9	4.7	40.5	23.1	4.82	0.56
Range	2.5-69.4	1.9-45.4	0.01-0.14	1.1-20.0	0.12-2.86	1.1-17.3	19-188	28-133	0-19.1	0-2.2

TABLE B12 Summary of acute changes in welders' and controls' pulmonary function results over shift period (afternoon value - morning value) 19 smokers, 6 non- and ex-smokers . Shift Trial

Lung function	Smoking habit	Welders Mean	Welders SD	Electrical fitter Mean	Electrical fitter SD
FEV_1 (1)	Smokers	-0.003	0.174	-0.032	0.109
	Non-smokers	-0.010	0.065	-0.133	0.113
	Total	-0.005	0.154	-0.056	0.117
FVC (1.)	Smokers	-0.058	0.255	-0.042	0.148
	Non-smokers	-0.012	0.152	-0.145	0.105
	Total	-0.042	0.235	-0.066	0.144
FEV_1/FVC(%)	Smokers	0.947	3.374	-0.105	2.052
	Non-smokers	-0.833	2.483	0.333	2.422
	Total	0.520	3.229	-0.160	2.095
RV (1.)	Smokers	-0.020	0.170	-0.005	0.080
	Non-smokers	-0.135	0.137	0.010	0.050
	Total	-0.047	0.168	-0.001	0.074
TLC (1.)	Smokers	-0.022	0.267	-0.044	0.143
	Non-smokers	-0.112	0.163	-0.063	0.071
	Total	-0.044	0.246	-0.049	0.128
TL^1	Smokers	0.105	0.543	-0.058	0.668
	Non-smokers	-0.050	0.625	0.217	0.656
	Total	0.068	0.554	0.008	0.662
/FET	Smokers	-0.047	0.330	0.015	0.186
	Non-smokers	0.020	0.117	0.008	0.171
	Total	-0.031	0.292	0.132	0.179
$MEF_{50}(1.s^{-1})$	Smokers	-0.155	0.511	-0.016	0.264
	Non-smokers	-0.140	0.423	-0.182	0.226
	Total	-0.151	0.480	-0.058	0.260
$MEF_{25}(1.s^{-1})$	Smokers	-0.072	0.305	-0.016	0.118
	Non-smokers	-0.120	0.226	-0.092	0.177
	Total	-0.084	0.282	-0.035	0.134

No significant differences

TABLE B13 Correlation co-efficients of acute change in lung function tests and measured fume/gas in breathing zone in 25 welders each studied for 1 day shift

		Lung function test							
		FEV_1	FVC	FEV%	RV	TL^1	$\sqrt{FET}$	MEF_{50}	MEF_{25}
Total fume	Smokers	-0.218	-0.168	-0.210	0.443	-0.146	0.406	-0.556*	-0.455
	Non-smokers	0.684	-0.201	0.252	0.567	0.214	-0.000	-0.110	0.724
	Total	-0.116	-0.158	-0.134	0.420*	-0.062	0.347	-0.449*	-0.235
Resp. fume	Smokers	-0.141	-0.220	0.013	0.528*	0.184	-0.063	-0.393	-0.536*
	Non-smokers	0.657	-0.415	0.460	0.576	0.290	0.008	0.069	0.891*
	Total	-0.011	-0.227	0.108	0.464*	0.207	-0.038	-0.231	-0.128
Fe_2O_3	Smokers	-0.150	-0.039	-0.281	0.451	-0.069	0.535*	-0.524*	-0.448
	Non-smokers	0.586	-0.180	0.176	0.543	0.162	0.122	-0.131	0.727
	Total	-0.064	-0.048	-0.200	0.422*	-0.015	0.458	-0.433*	-0.228
ZnO	Smokers	0.026	0.116	-0.220	0.388	-0.159	0.494*	-0.433	-0.371
	Non-smokers	0.588	-0.165	0.191	0.5	0.10	0.148	-0.180	0.742
	Total	0.090	0.066	-0.136	0.369	-0.080	0.398*	-0.350	-0.118
NO_x	Smokers	-0.095	-0.183	0.046	0.407	0.191	-0.135	-0.099	-0.180
	Non-smokers	-0.538	-0.026	0.155	0.621	-0.086	0.282	-0.405	0.716
	Total	0.011	-0.130	0.076	0.425*	0.089	-0.058	-0.190	0.071
CO	Smokers	0.226	0.158	0.032	0.283	-0.20	-0.266	0.187	-0.216
	Non-smokers	-0.515	-0.253	0.262	0.503	0.153	0.228	-0.089	0.861*
	Total	0.233	0.063	0.138	0.383	0.033	-0.253	0.143	-0.071

*Significant at 5% level (no values significant at 1% level)

TABLE B14 Concentration of metals in blood

Day Number	Mn (ug/ml whole blood)				Cu (ug/ml whole blood)				Zn (ug/L whole blood)			
	Welder		Matched control		Welder		Matched control		Welder		Matched control	
	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm
1	3.3	4.9	3.1	2.3	0.12	0.12	0.13	0.12	0.51	0.46	0.38	0.36
2	3.2	3.2	2.9	2.1	0.12	0.12	0.12	0.11	0.44	0.42	0.35	0.32
3	2.7	2.2	2.3	4.5	0.11	0.10	0.12	0.11	0.47	0.36	0.43	0.37
4	2.6		3.0		0.11		0.09		0.31		0.42	
5	2.7	3.1	2.8	2.5	0.11	0.11	0.13	0.13	0.37	0.36	0.51	0.50
6	2.2	2.0	1.5	3.0	0.13	0.11	0.09	0.11	0.39	0.34	0.24	0.26
7	2.0	6.0	2.1	2.6	0.11	0.12	0.11	0.12	0.43	0.41	0.40	0.38
8	3.9	3.6	3.2	2.9	0.14	0.14	0.14	0.15	0.37	0.33	0.13	0.10
9	5.6	3.2	3.0	2.6	0.17	0.18	0.15	0.14	0.35	0.35	0.40	0.39
10	5.8	4.0	3.4	3.5	0.10	0.11	0.15	0.14	0.41	0.41	0.46	0.42
11	1.8	1.7	3.9	4.4	0.10	0.12	0.11	0.13	0.24	0.21	0.47	0.46
12	1.2	1.6	3.0	2.6	0.09	0.10	0.13	0.13	0.47	0.45	0.41	0.46
13	2.7	4.6	1.7	2.0	0.13	0.13	0.10	0.10	0.36	0.36	0.40	0.37
14	2.2	1.8	1.1	1.0	0.10	0.09	0.13	0.11	0.46	0.43	0.41	0.41
15	3.4	4.1	3.5	2.8	0.10	0.11	0.12	0.12	0.39	0.40	0.37	0.35
16	1.4	2.1	1.0	1.3	0.12	0.14	0.08	0.08	0.40	0.43	0.45	0.37
17	5.9	4.6	1.5	1.8	0.13	0.14	0.13	0.14	0.34	0.33	0.43	0.39
18	1.5	1.3	2.9	2.9	0.11	0.13	0.12	0.12	0.42	0.42	0.56	0.54
19	1.8	2.0	1.3	1.0	0.12	0.13	0.12	0.11	0.34	0.36	0.43	0.41
20	3.5	3.6	2.4	1.9	0.11	0.13	0.12	0.12	0.42	0.40	0.31	0.29
21	4.1	4.4	2.7	2.8	0.11	0.11	0.14	0.13	0.38	0.38	0.42	0.39
22	2.3	1.4	2.1	1.4	0.12	0.13	0.13	0.13	0.27	0.32	0.35	0.29
23	4.1	4.2	2.3	1.9	0.12	0.12	0.13	0.14	0.46	0.48	0.37	0.40
24	4.5	4.1	1.3	1.2	0.14	0.14	0.11	0.11	0.38	0.34	0.39	0.42
25	2.8	3.2	3.2	5.9	0.12	0.11	0.13	0.12	0.40	0.41	0.42	0.43
Mean	3.1	3.2	2.4	2.5	0.12	0.12	0.12	0.12	0.40	0.38	0.39	0.38

TABLE B15 Cases of siderosis among welders, as reported by various authors

Author	Number of welders studied	Number of cases of siderosis
Ahlmark and Lonneberg (1953)	110	0
Hunnicutt et al (1964)	100	34
Kleinfeld et al (1969)	25	8
Peters et al (1973)	61	0
Schuler et al (1962)	210	32
Fogh et al (1969)	156	5
Barhad et al (1975)	50 (all smokers)	18

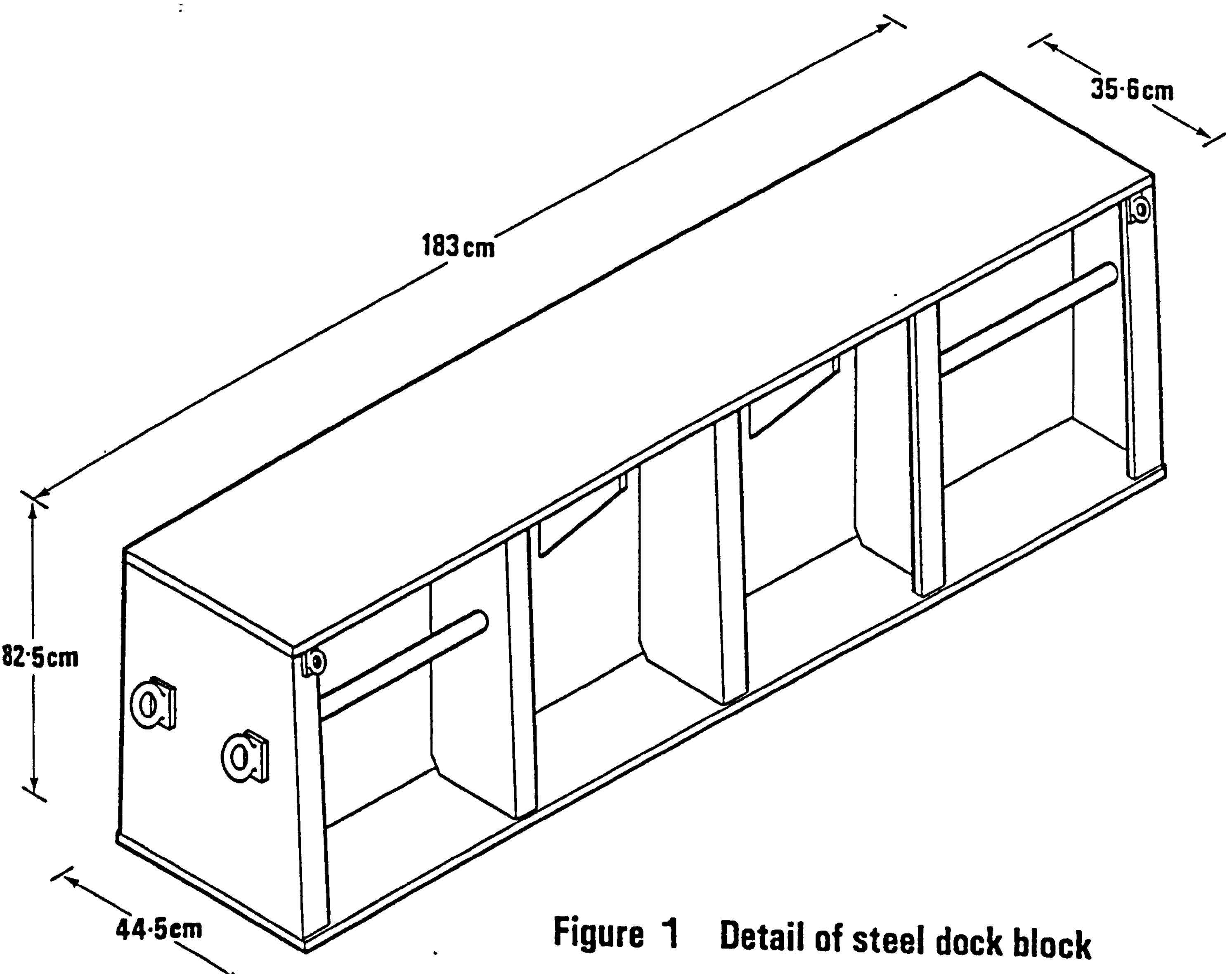
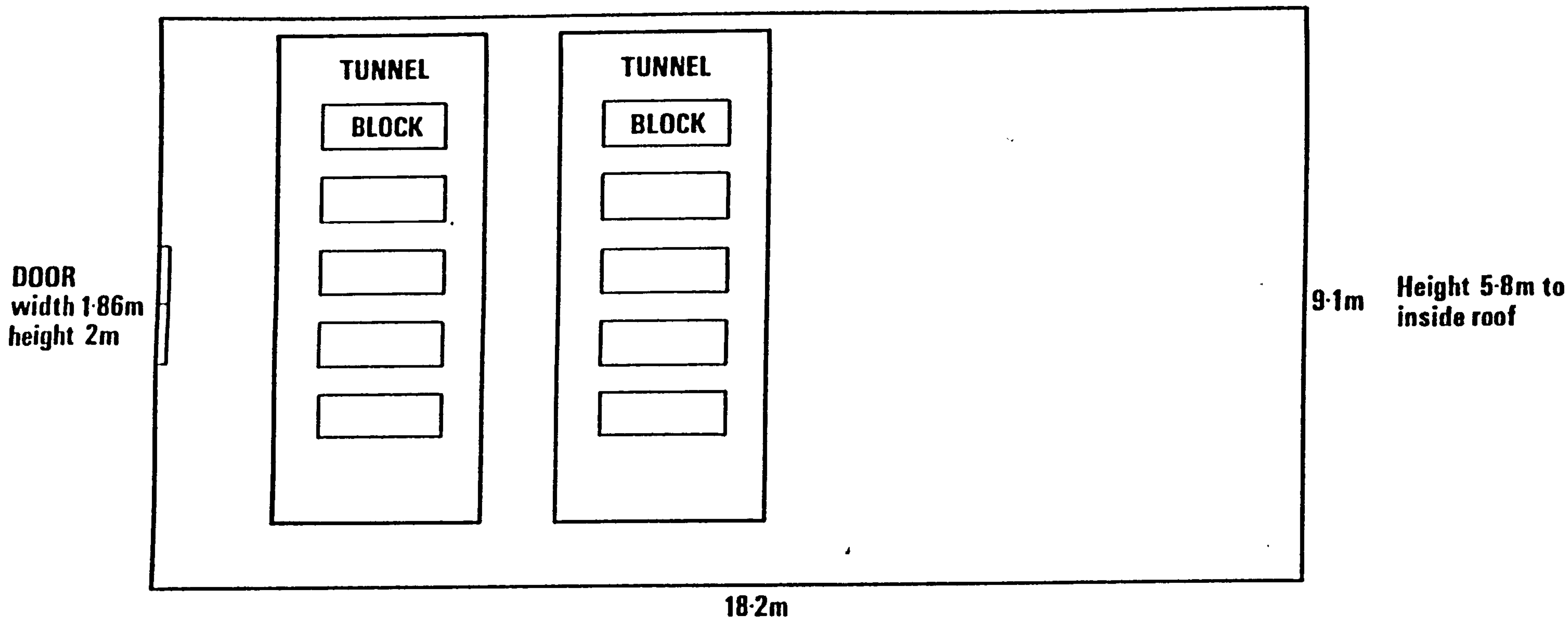
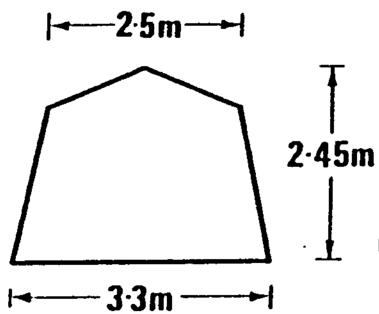


Figure 1 Detail of steel dock block

Figure 2 Plan of welding rig showing positions of dock blocks and shelters





Cross-section of tunnel

Figure B3 Igloo shelter used to construct tunnel within welding grid

Figure B4 Welding grid showing tunnel and dock block

Figure B5 Welding grid with roof sections in place

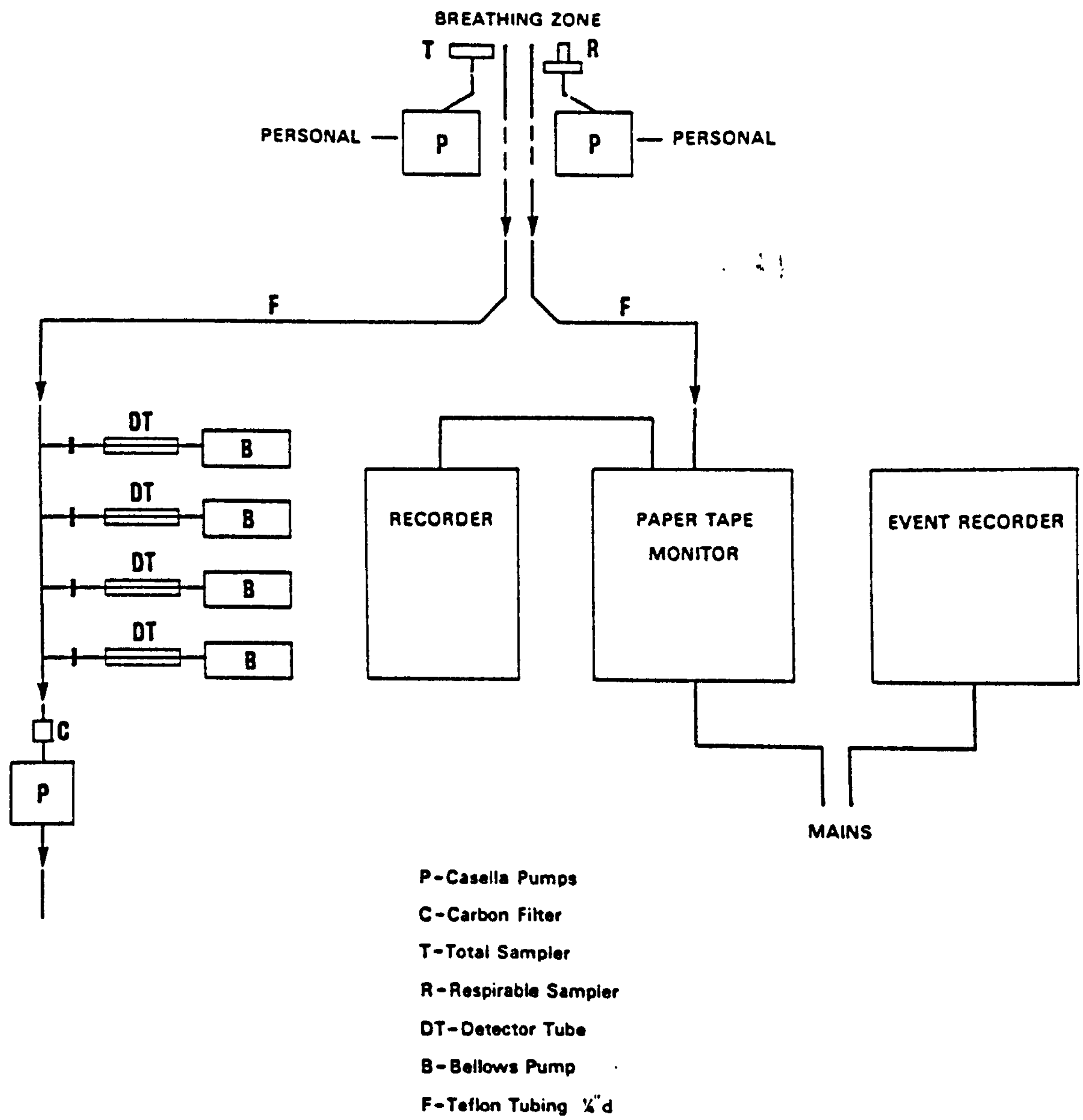


Figure B6. Line diagram of sampling equipment

Figure B7 Welder working on dock block within tunnel

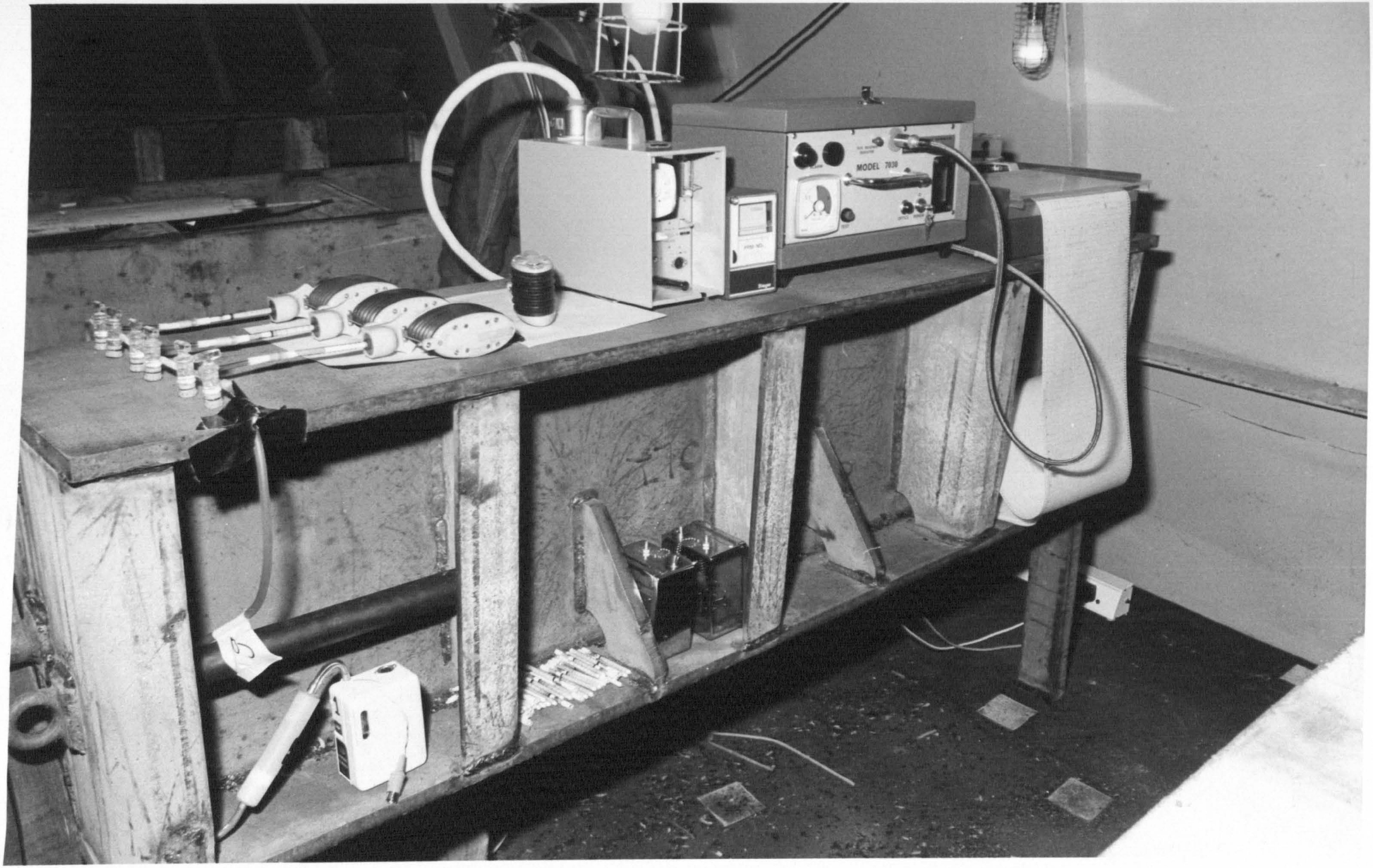


Figure B8 Interior of tunnel showing dock blocks and sampling equipment

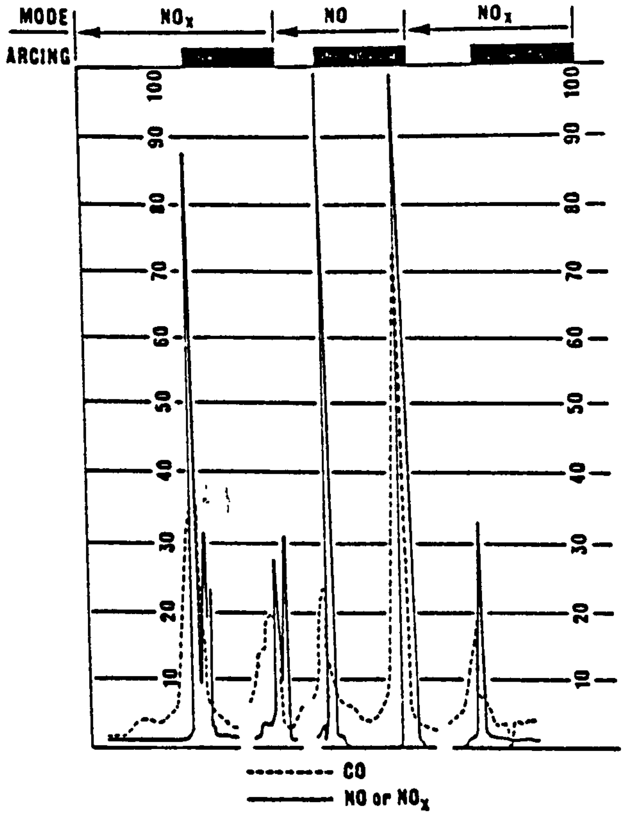


Figure B9. Typical section of recorded output from automatic analysers for NO, NO_x and CO.

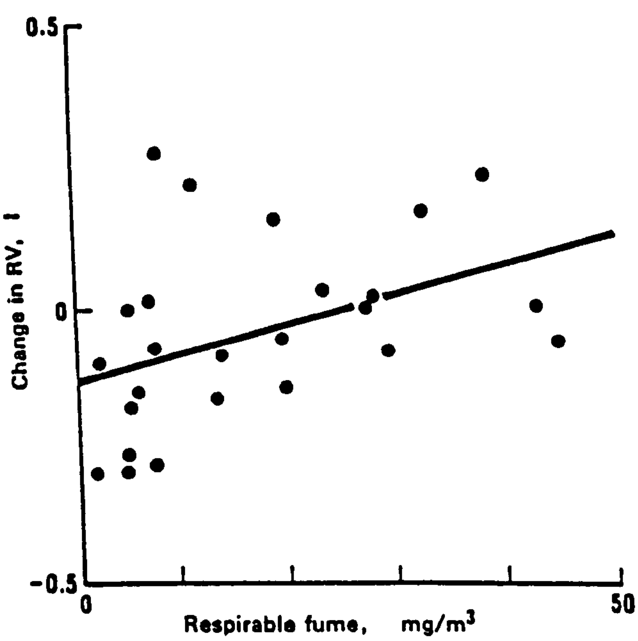


Figure B10. Acute shift change in RV v. respirable fume concentration.

SECTION C

CLINICAL, RADIOLOGICAL AND LUNG FUNCTION STUDY OF 328 WELDERS

Summary

Three hundred and twenty eight of 368 welders at HM Dockyard's Devonport, Portsmouth and Chatham were examined including full size PA chest radiograph and lung function testing. Radiographs were read independently by a panel of three readers. Almost all the welders had had no other job and most worked at manual metal arc welding. Some eighty per cent had been exposed to asbestos. Two hundred and fifty smoked or had smoked.

Thirty three men (only one non-smoker) had chronic bronchitis. Fourteen had dyspnoea. Two hundred and twenty had had metal fume fever. Recent attacks were most common in middle age men.

Eighty eight men had abnormal lung function patterns. Obstructive changes were most common. Non-smokers were least affected. Prevalence increased with duration of exposure and age.

Eighteen men had radiographic changes compatible with a diagnosis of siderosis. There was no constant relationship with exposure, clinical abnormality nor functional impairment. Eleven men had asbestos related parenchymal changes and 73 men had pleural fibrosis.

It is concluded that there is no definite evidence of welding causing or aggravating respiratory disease but the lung function abnormalities merit a case control study of the older men.

1. INTRODUCTION

This study of respiratory health of Dockyard welders was originally designed to allow comparison between men with siderosis and those without that radiological abnormality and thus determine if it had any related clinical and/or physiological abnormalities. However, too few had the abnormality to permit any meaningful comparisons. This report describes the findings of the clinical, radiological and physiological examinations and compares them with welders studied by other researchers. Considerable caution is exercised in these comparisons as any effects on health are likely to be dose-related and the exposure patterns of other welding groups are seldom described. The findings in Dockyard welders aged 45 years and over have been used in a case control study reported on in Part 2 of Project 14/76.

2. MATERIAL AND METHODS

2.1 Population and its work

Three hundred and twenty eight craftsman welders employed at HM Dockyard's Devonport, Portsmouth and Chatham accepted an invitation to have a clinical examination, full size PA chest radiograph and pulmonary function tests (FEV_1, FVC, RV, TLC and gas transfer factor). Forty welders (10.9%) were not examined. Thirty four refused (Devonport 14, Portsmouth 14, Chatham 6) and six at Chatham were unavailable as they had been temporarily transferred to Rosyth.

The welding tasks and potential exposure to fumes and gases are described in the report of ERWP Project 8/75 and Evans et al (1979), and definition of smoking habit categories is made in the report of ERWP Projects 9/75 and 11/76.

2.2 Examinations

The clinical examinations and interviews were conducted by the project officer using the questionnaire at the end of this report. Results of lung function tests were used to categorise subjects by LFT pattern (normal, obstructive, restrictive and mixed) as described by Hunnicutt et al (1964).

2.3 Radiograph interpretation

Personal identification features were masked on the full size PA chest radiographs which were read independently, in random order and mixed with radiographs from other studies to the ILO U/C 1971 Classification by three experienced readers (Drs G Sheers, J C Gilson, P Elmes). In an attempt to reduce inter-reader variation a selection of full size chest radiographs from other surveys of the Dockyard population which were considered to exhibit the complete range of asbestos related lesions, other pathologies or no abnormalities was presented to the three readers in committee and they were required to agree on the ILO U/C Classification of each radiograph. These radiographs could not be distinguished from the survey films and were mixed randomly in the ratio 1:7 in each batch of films during the independent reading. Each reader's clerk could identify the "trigger films" from the reading sheet and, after the reader had dictated his classification he was presented with the agreed classification for comparison in the hope that variation in reading standard would be minimised. For every aspect of radiographic abnormality the agreed reading of at least two of the three readers has been used in the tabulation.

2.4 Follow-up actions

Any significant abnormalities found in the study were reported with the man's permission to his doctor.

3. RESULTS

3.1 Population

Some two thirds of the welders were aged 40-59 years and 9.8% were over 60 (table C1). Seventy six per cent had been welders for at least twenty years (table C2) and, as indicated by the very small differences between time as a welder and time since first employed in that craft (table C3), virtually all had remained welders once started.

Almost all (95.7%) were employed mainly on manual metal arc welding (table C4), eight of the remainder spending most of their time on tungsten inert gas welding, five on metal inert gas and only one on oxyacetylene welding. Manual metal arc work was spread fairly evenly through the age groups as was the small number of men doing tungsten inert gas welding (table C5). The five men on metal inert gas welding were aged 30-50 years.

Two hundred and sixty seven (81.4%) had used asbestos materials to protect themselves from hot metal spatter during welding with little variation over the age of 30 while fewer of the younger men (34.1%) had been exposed (table C6). Only 55 men (16.8%) had done any asbestos lagging or delagging themselves but 176 (53.7%) had been exposed to asbestos during limpet spraying and 164 (50.0%) during other asbestos work by other men. Exposure to the high levels of dust in limpet spraying was much more common in men over 40 years of age and to other asbestos work in men over 30 years.

Two hundred and fifty men (76.2%) smoked or had smoked in the past (table C7). The proportion of non-smokers was highest in the younger age groups.

3.2 Respiratory symptoms (table C9)

Sixty two men (18.9%) reported producing phlegm each morning for at least 3 months in each of the previous two years. This was nine more than reported chronic cough, the difference being mainly in those who had been welding for the shortest time. There were no constant time-symptom relationships.

Chronic cough and phlegm (chronic bronchitis) was reported by 33 men (10.1% of the total). Only one of these was a non-smoker. None had been welding for less than 10 years and increasing time exposed to welding did not produce a corresponding increase in the proportion with chronic bronchitis symptoms.

Fourteen men reported dyspnoea when walking on the level with others of the same age group and all but 3 of these were over 50 years. Again there was no apparent relationship with duration of exposure.

3.3 Respiratory system signs (table C10) and blood pressure (table C11)

Few men were found to have positive clinical signs on examination of the respiratory system. One man had finger clubbing attributed to asbestos induced parenchymal fibrosis. None had cyanosis nor tracheal deviation. One man had dullness to percussion which proved to be a pleural effusion due to a previously undiagnosed bronchial carcinoma. Eighteen men (5.5%) had persistent basal rales, the "crackles" which are often found as an early sign of asbestos induced parenchymal fibrosis. These were twice as common in those who had been welders for 30 years or more. One had a restrictive defect on spirometry. Twenty two men (6.7%) had rhonchii, all smokers, the proportion increasing with time as a welder. Twelve of these men had obstructive or mixed obstructive and restrictive ventilatory defect when spirometry was performed. Both men with pleural creaking had no other signs and a history of pleurisy years earlier and both men with areas of local tenderness had had recent sports injuries.

One hundred and sixty three (49.7%) of men had a blood pressure exceeding 140/90 mm Hg after rest with a steady increase in percentage affected with increasing age.

3.4 Metal fume fever (table C12)

Two hundred and twenty one men (67.4%) had had metal fume fever at some time in their time as welders. Only 37 (11.3%) had an episode in the year prior to interview, the attack rate being relatively low in the least and most experienced men.

3.5 Pulmonary function tests (table C13)

Eighty eight of the welders had abnormal lung function patterns with obstruction predominating (table C13). Abnormalities were more than twice as common in those who smoked or had smoked. The prevalence of each and all types of abnormality generally increased with length of exposure to welding though, of course, that in turn virtually parallels age.

3.6 Chest radiographs (tables C14-18)

Radiographs of acceptable quality were available for all but 11 men (3.4%). Although there were variations in readers' classifications (table C14) these were not statistically significant.

Forty three radiographs had an "agreed" ILO 1979 Classification of 0/1 or more for small rounded opacities but only 18 (5.5%) were 1/0 or more, the standard taken as indicating a definite abnormality. 1/1 was the highest agreed classification (table C14) and 7 men were in that category.

No-one with less than 16 years as a welder and 25 years since entering the trade had an abnormality and only one with less than 20 years as a welder (table C15). Four men with 20-29 years exposure, 12 men with 30-39 years exposure and one man with over 40 years exposure had x-ray classification of 1/0 or over and thus compatible with a diagnosis of siderosis.

Of the eleven men with category 1/0 small opacities, one had a definite restrictive ventilatory defect, one had a minimal restriction (FVC_a/FVC_p = 88%)

and one had obstructive changes on spirometry. One man with category 1/1 had a slight restrictive defect (FVC_a/FVC_p = 86.2%) and one had obstructive changes.

Reader's variation in classifying x-rays by presence of small irregular opacities (table C15) were not statistically significant. Eleven welders had classification 1/0 or over suggesting parenchymal fibrosis attributable to asbestos. Only one had been welding for less than 20 years.

The readers agreed better on pleural fibrosis. Seventy three men had plaques or pleural thickening and in twenty one of these there were calcified pleural plaques, all attributable to asbestos exposure.

4. DISCUSSION

4.1 General

The value of studies of the health of survivor populations without controls is limited. As stated in the introduction to this report it had been hoped to compare and contrast those who had radiographic abnormalities of siderosis but cases of this abnormality were too few to give any meaning to such comparisons. However, as the work of these welders has been detailed (unlike most other studies) it is thought worthwhile to record the findings and relate them to the hypothesis that welding does not produce respiratory disease, and to published work.

The first major investigation of welders' health was conducted by Doig and Duguid (1951) in the mid 1940's. Having studied 245 welders in British heavy engineering they concluded that welders did not suffer from a specific occupationally related disease but drew attention to the incidence of arc eye, throat irritation, catarrh and frequent colds which were especially related to working in enclosed spaces and with galvanised metal. There was an increased incidence of lower respiratory tract symptoms in those with the longest exposure to welding but unfortunately no mention is made of the men's smoking habits. Their conclusions were supported by a similar study in America of 4560 welders employed in shipyards (Dressen et al, 1947), and by Sander (1944) in a smaller group of welders. Schuler et al (1962) and Hunnicutt et al (1964) found no impairment of the general health of welders.

Later reports have drawn attention to the differences in incidence of general symptoms in varying work environments and processes. For example deKretser and his colleagues (1964) reported that the excess incidence of respiratory symptoms among 8 welders relative to other workers in the same workplace was reduced to that of the controls when improvements were made in fume control. Fogh et al (1971) reported frequent complaints of subjective discomfort among welders using low hydrogen electrodes but formal study showed no increase with increasing use of the electrode, and Ross (personal communication) found that fumes from these electrodes, stainless steel and other "special" rods gave rise to complaints of obnoxious smell, black spit, running noses, sore throat, watering eyes, cough and a metallic taste. Sjogren (1977) found significantly excessive incidence of similar symptoms in welders who used MIG and TIG processes for much of their working day but did not detect any corresponding lung function abnormalities. Welders studied by Antti-Poike et al (1977) reported frequent colds, sore throats, hoarseness and fevers more often than controls.

Sevcik and his colleagues (1960) reported that welders are subject to muscular weakness, neuraesthenia and eye changes. Hoschek (1970) found an excess of gastric disorders among his welders and suggested that these were related to stress. Magnusson (1974) reported that welders suffered short episodes (without absence from work) of giddiness, nausea and fever. Kadefors et al (1976) and Petersen et al (1976) used electromyography in an investigation of muscle fatigue during welding. They found that there was real muscle fatigue especially related to overhead welding and that while experience lessened the effect in terms of muscle groups involved it did not confer immunity and all welders experienced discomfort during overhead welding. In the Dockyard study I chose to concentrate on respiratory health.

4.2 Chronic bronchitis and other lower respiratory tract diseases

Most investigators who have studied the prevalence of chronic bronchitis in welders have used the Medical Research Council definition of the disease - chronic productive cough each day for three consecutive months for two years. The importance of such a standard definition is demonstrated in this study where 96 men reported that they had had sick leave attributed to bronchitis (presumably acute or acute on chronic) while only 33 men (10.1%) had chronic productive cough. This is a much lower prevalence than reported by Sevcik et al (1960), Hunnicutt et al (1964), Fogh et al (1969), Barhad et al (1974), Slepika et al (1974), similar to that found by Peters et al (1973) and rather higher than Ross found in his Scottish welders (personal communication).

The excess prevalence in those with a positive smoking habit history has been noted by all those who examined this aspect though the Dockyard ratio of 32:1 is greater than found elsewhere.

The close correlation between age and the length of time men have been employed as welders is likely to make separation of any dose response relationship and increased incidence with age virtually impossible unless the effects of the antagonist were very powerful or the effect was unusual. Chronic bronchitis is a common disease. In this study the proportion of men affected actually varied very little with age. This may well be because the older men with the disease have already left. Other studies of this population provided no evidence that respiratory diseases were a major cause of welders retiring early on medical grounds or being relocated in other employment in the Yards. Sevcik and his colleagues (1960) found that chronic bronchitis was more common in those with longer exposure but the differences were not statistically significant. Dobrzynski (1974) found increasing prevalence with length of exposure especially amongst workers in confined spaces, Barhad et al (1975) and Antti-Poika et al (1977) found no dose response relationship.

Nine men reported morning phlegm without any noticeable cough and related this to working with low hydrogen electrodes. Dry cough was not a feature but has been described by Fogh et al (1969).

Only fourteen men (4.3%) reported noticeable dyspnoea; similar prevalence to that reported by Peters et al (1973) and in contrast to 20% found by Barhad and his colleagues.

4.3 Other pathology

Review of the literature suggests that very few investigators have conducted clinical examinations of welders, probably because the pick-up rate of undiagnosed disease is low. In this study it was thought essential to give the welders an opportunity to discuss their health at some leisure, to voice any anxieties they had and, after examination, to arrange for consultations with the general practitioners or relevant specialists when this was necessary. Physical examination was confined to the respiratory system and measurement of blood pressure after rest (the latter because it is a quick effective screening test) unless the history directed more extensive examination. Only one case of serious illness was diagnosed, the man with bronchial carcinoma, but several men with hernia and one with a massive hydrocele were referred for treatment. All 163 men with blood pressure of 140/90 mmHg or greater were referred to their general practitioner for investigation. Those men with persistent basal rales were notified to their local Yard Occupational Health Service for routine asbestos exposure surveillance.

Twelve of the men with rhonchii had an obstructive or mixed obstructive and restrictive ventilatory defect apparent on spirometry.

4.4 Metal fume fever

The welders described experience of metal fume fever was surprising as it had been expected that the youngest and thus least experienced welders would have the highest recent incidence but this was not the case; the middle aged tended to allow themselves to be affected, perhaps an example of familiarity breeding contempt.

Metal fume fever was first described by Thackrah in 1932. It is variously termed welders' or brass founders' ague, foundry fever, Monday fever (Petit, 1943., Viles, 1945., Doig and Duguid, 1951., Chmielewski et al, 1974., Jaremin et al, 1974., Ross, 1974) and in the Dockyards "galvanised poisoning" indicating the welders' appreciation that it is most commonly associated with the zinc fume arising from the galvanised surface coating of metal. Many other metals such as iron, copper, magnesium, aluminium, antimony, manganese, nickel, selenium, silver, mercury and tin have been reported as causes (Brodie, 1943., Rohrs, 1957., Glass, 1970., Ross, 1974). The welding situation is usually confined and inadequately ventilated.

Frequently several incidents arise from one situation, for example in one Yard investigated by the writer, welding the thin galvanised flanges of ventilation trunking in a ship had caused symptoms in all the welders involved. The thinness of the metal sheeting had prevented the galvanised zinc being ground off before welding. The situation was not especially confined (the main passageway and mess decks of a frigate) and the welders had not used any extraction. Even when the coating is removed from the area to be welded substantial amounts of fume may arise from volatilisation of zinc several inches from the weld by conducted heat.

It is an unpleasant acute illness which usually begins in late afternoon or early evening and is most often over within 24 hours. Few welders lose work because of it. Severity varies considerably (Dressen et al, 1947) but usually the welder suffers intense bouts of shivering, inability to keep warm and an undulating low grade pyrexis (Hamilton, 1925., Petit, 1943., Drinker and Nelson, 1944., Papp, 1968., Fishburn and Zenz, 1969., Department of Employment, 1972). In more severe cases there is chest pain and/or abdominal pain with vomiting and rarely the illness may be complicated by metal-specific poisoning, for example cadmium or mercury, or by pneumonia or pneumonitis (Williams, 1935., Doig and Duguid, 1951., Fishburn and Zenz, 1969., Ross, 1974., Anthony et al, 1978). Ross (1974) reported that 31% of welders aged 20-59 years had had at least one attack while Dressen and his colleagues (1947) found an incidence of 10%.

The condition is caused by inhalation of freshly formed metallic oxides and these are present in welding fume. The particles are less than 1 μ in diameter at this stage (Petit, 1943) and can reach the alveoli causing tissue damage, formation of an immune complex and release of a histamine like substance (McCord, 1960). Urinary zinc concentration may be elevated (Anthony et al, 1978). There may be elevation of the serum levels of metals (Fishburn and Zenz, 1969) but this is not a constant feature and more usually these remain normal (Ross, 1974). Elevated levels of the serum pulmonary isoenzyme for lactic dehydrogenase, an indicator of pulmonary tissue damage, may be detected (Fishburn and Zenz, 1969). Ohmoto et al (1974) consider that damage to mucosal epithelium as a primary response is not a prerequisite for metal fume fever. After the fume particles have been in the atmosphere for a short time they flocculate and the resulting conglomerates may be too large to reach alveolar level.

Metal fume fever is reported to be more common after a period of absence from work (even a weekend) (Ross, 1974) and in the winter (Sayer, 1938) and apparently some welders believe that an attack early in the week confers temporary immunity (Ross, 1974). This view has some support in the literature (Hamilton, 1925., Engel, 1934., Petit, 1943., Drinker and Nelson, 1944., Anseline, 1972., Pierce, 1972). From knowledge gained during the writer's investigation alternative explanations appear equally if not more acceptable. The welder is less likely to be cautious about avoiding inhalation of fume as the period since an attack of metal fume fever increases, for example after a holiday, and conversely more cautious when he has recently had an attack, perhaps earlier in the week. Additionally it has been found that welders who report an attack to their supervisors tend not to be employed in confined spaces for the next few days.

The increased incidence in winter could be explained by welders combatting low environmental temperatures by closing access doors which otherwise provide some degree of natural ventilation. When this is removed and no alternative ventilation is provided fume concentrations and the incidence of metal fume fever would be expected to rise.

4.5 Lung function abnormalities

Eighty eight (26.8%) of the welders had abnormal lung function patterns with obstructive changes more common than others. The criterion set by Hunnicutt et al (1964) for a restrictive defect is perhaps rather strict and several welders only just "qualified".

The prevalence was markedly lower than that described by Hunnicutt and his colleagues (1964) where 40.7% of the shipyard welders were affected, and lower than in studies by Meo et al (1966) and Fogh et al (1969). They also found obstructive changes to be the most common in contrast to the restrictive defects found in a third of heavy engineering and shipyard welders with heavy exposure to fume (19-30 mg/m^3) reported by Kierst et al (1964) and the predominance of restrictive defects found by Barhad et al (1975) in shipyard welders.

Although previous work has shown increased prevalence of lung function abnormalities with increased fume concentration there has been no demonstration of correlation with duration of exposure. Although the Yard welders do show increased prevalence with greater exposure duration the latter equates with age and no firm conclusions from this can be drawn in this uncontrolled study.

The effect of smoking on lung function is quite definitely demonstrated as 55.6% of those with a positive smoking history had abnormalities compared to only 20.5% of those who never smoked. However, the "protection" afforded by not smoking is less apparent in obstructive disorders than restrictive and the fact that 10 non-smokers had obstructive disease patterns could suggest that welding may have contributed to that disorder.

4.6 Arc welders' pneumoconiosis

No other aspect of welders' health has excited more attention than the radiologically apparent pulmonary nodulation exhibited by a varying proportion of welders and often referred to as welders' lung. The writer considers that this condition should be called arc welders' pneumoconiosis and subdivided into simple, in which there is no pulmonary fibrosis nor significant effect on health, and complicated where there is fibrosis and may be adverse effects on health. The latter appears to be uncommon .

The prevalence of siderosis reported by authors is summarised overleaf. As exposure to fume and the diagnostic criteria may very considerably and are seldom described comparisons must be made with caution. I consider that the minimum classification of 1/0 used to determine the prevalence of small regular rounded opacities in the Yard welders is the lowest realistic value which can be used with any certainty; 1/1 would be more definite. With these caveats in mind it can be said that the Yard prevalence of 5.5% 1/0 or over is encouragingly low especially as 1/1 was the highest category read.

Prevalence of siderosis in published studies

Author	Number of Welders	Percentage with Siderosis
Spacilova and Koval, 1975	37	80
Barhad et al, 1975	50	36
Hunnicutt et al, 1964	100	34
Kleinfeld et al, 1969	25	32
Stanescu et al, 1967	52	31
Donoso et al, 1974	57	28
Lucciomi et al, 1966	163	18
Schuler et al, 1962	210	17
Pikulskaya and Gulko, 1975	473	13
Haglind, 1957	450	10
Britton and Walsh, 1940	256	10
Fogh et al, 1969	156	8
Grohr, 1944	80	7
Sander, 1944	500	7
Attfield and Ross, 1978	66	7
Ahlmark and Lonnberg, 1953	110	0
Peters et al, 1973	61	0

Doig and McLaughlin (1936) were the first to show that electric arc welders could develop radiologically apparent lung changes associated with their occupation when they described a series of sixteen welders six of whom had fine stippling or mottling and small irregular nodularities with soft margins in the lung fields shown on a PA chest radiograph. No histological evidence was available to them and while suggesting that these shadows were due to the inhalation of iron oxide in welding fume they could not rule out the possibility of silica or asbestos as a causative agent. Zenker (1867) had already recognised the presence of iron oxide in the lungs of other workers and called the condition siderosis. Charpin (1965) described three stages; an increase in hilar image, increase in size of hila and reticular lung image and a miliary appearance.

Enzer and Sander (1938) confirmed histologically that the appearances noted by Doig and McLaughlin were due to iron oxide while Harding alone (1945) and with his colleagues (1947) replicated the situation experimentally. It was concluded that the shadows were due to the radio-opacity of iron oxide particles accumulated in the peribronchial and perivascular lymphatics and on alveolar septa. The absence of fibrosis was noted by these workers and Sander (1944) and this was confirmed by later work among welders and in other trades. (Barrie and Harding, 1947., McLaughlin et al, 1945., Harding, 1948., Hamlin and Webber, 1950., Vorward et al, 1950., Haglind, 1957., Mann and Lecutier, 1957., Harding et al, 1958., Oyanguren et al, 1958., Hamlin, 1959., Schüler et al, 1962., Morgan and Kerr, 1963). One welder studied by Morgan and Kerr (1963) had no histological evidence of fibrosis despite the iron content of his lung being 15 times the normal defined by Tipton.

Enzer and Sander (1938) considered that the concentration of welding fumes was more critical to the development of siderosis than the duration of exposure. It is thought that there is probably a critical concentration beyond which muco-ciliary and lymphatic clearance cannot prevent the accumulation of iron oxide particles but there is insufficient exposure data and lack of precise radiological definition of the changes termed siderosis in the studies reported in the literature to evaluate the hypothesis of Enzer and Sander. Reported prevalences range from zero (Peters et al, 1973) to 80% (Spacilova and Koval, 1975), the latter occurring in a group of welders stated to have been exposed to high concentrations of fume as had those of Grohr (1944).

Mouton (1976) described three patients with pulmonary microreticular nodulations on their chest radiograph. They had worked for 8, 10 and 14 years using MIG (argon and carbon dioxide) welding in an enclosed environment where concentrations of pollutants were 10-30 times TLV. These men had no clinical symptoms and virtually normal lung function. Biopsies of two showed numerous siderophores and ferruginous material.

The welders studied by Kierst et al (1964) were exposed to breathing zone concentrations of 19-30 mg% total fume, 70-80% being ferric oxide. Quite distinctive features of pneumoconiosis developed in some cases after only two years exposure. The majority of workers have found that few if any cases developed before 5-15 years exposure after which the prevalence increases steadily (Haglind, 1957., Schuler et al, 1962., Charpin, 1965., Luccioni et al, 1966., Einbrodt et al, 1971., Sadoul, 1972., Attfield and Ross, 1978), to about 30% on retirement (Attfield and Ross, 1978) and not exceeding ILO Classification 2/2 (Sadoul, 1972). The Yard findings conf rm to this pattern.

Group mean exposure levels can be very deceiving as the personal variation between welders is often very considerable (Ouw et al, 1977., Kalliomaki et al, 1978b., Evans et al, 1979). This may explain the findings of Hunnicutt et al (1964) that there was no significant difference in duration of exposure between welders with and without siderosis and of Kleinfeld et al (1969) who found no correlation between duration of exposure and x-ray appearances. A method of measuring the amount of ferromagnetic lung contaminants in vivo has been developed by Cohen (1973) and Kalliomake et al (1976) and applied to welders (Kalliomaki et al, 1977, 1978a, b, c). In 100 shipyard arc welders they found that the amount of lung contaminants varied greatly between individuals working in similar conditions. Similar variation has been found in post-mortem studies of miners who had experienced a very homogenous exposure, (Stober et al, 1965., Rossiter et al, 1965). In the welders who had been exposed for over five years the amount of dust contaminants was independent of exposure time and it was concluded that a constant level of contamination is achieved after five years.

Too few Yard welders had siderosis to draw any conclusions about the effect of smoking on the prevalence of that x-ray appearance. Hunnicutt and colleagues (1964) found that smoking habit did not appear to affect the proportion of welders who had an abnormal chest radiograph. Among his welders 68% with an abnormal film and 71% with a normal film were smokers.

Several workers have conducted clinical and/or lung function studies of welders with siderosis. The majority have found no significant abnormalities (Enzer and Sander, 1938., Killick, 1938., Sander, 1944., Enzer et al, 1945., Schiotz, 1945., Doig and McLaughlin, 1948., Haglind, 1957., Schuler et al, 1962., Morgan and Kerr, 1963., Hunnicutt et al, 1964., Kierst et al, 1964., Kujawska et al, 1975., Malik and Ulrich, 1975., Spacilova and Koval, 1975., Mouton, 1976) or as in this study there has been no consistent correlation between symptoms nor functional impairment and the x-ray appearance (Doig and Duguid, 1951., Luccioni et al, 1966). Donoso et al (1974) considered that siderosis is associated with obstructive lung dysfunction while Stanescu et al (1967) and Šlepika et al (1970 and 1974) demonstrated reduction in static and functional compliance, a restrictive dysfunction in keeping with parenchymal fibrosis. Morgan (1962) described progressive massive fibrosis in welders' siderosis. Parenchymal lung tissue adjacent to but not involved in the conglomeration showed no fibrosis despite the presence of iron in the alveoli and terminal bronchioles.

Further evidence in support of the absence of fibrosis was provided by Doig and McLaughlin (1948) who observed radiological improvement (regression of opacities) in welders after exposure to welding fume ceased. Regression has also been reported by Haglind (1957), Garnuszewski and Dobrzynski (1967), Kujawska et al (1975), and Pikulskaya and Gulko (1975). It is thought unlikely that such regression could be observed if the nodulation and reticulation was due to fibrosis.

On balance of evidence it could be concluded that arc welders' siderosis is a benign condition and this view is accepted by most authors. The majority of those who disagree with this conclusion (Charr, 1953, 1955 and 1956., Mayer and Rappaport, 1954., Mann and Lecutier, 1957., Sevcik, 1960., Friede and Rachow, 1961., Kierst et al, 1964., Charpin, 1965., Einbrodt, et al, 1971., Cassan, 1972., Irmscher et al, 1975) and consider it to cause respiratory symptoms, dysfunction or even death, have reported individual cases or small series, often highly selected, and these may be examples of gross overexposure and/or hypersusceptibility.

On the other hand argument against the belief that the condition was not fibrotic began in the late 1950's and early 1960's and may be a result of the introduction of coated rather than bare electrodes producing a new or modified condition. The composition of the mixture of pollutants arising from welding processes is complex and it would be surprising if all the materials acted independently on the lung their behaviour unmodified by one another.

Harding et al (1958) and Luccioni et al (1966), considered that any fibrosis was due not to iron oxide but to other constituents of welding fume or possibly to some of the gases. Jones and Warner (1972) reported that iron oxide alone was not fibrogenic but when combined with other metallic dusts such as chromium oxide and nickel oxide. Casanouve and Soudan (1961) considered iron oxide alone to be fibrogenic but it is thought unlikely that their iron miners had an unmixed exposure.

While chromium nickel oxides are relatively limited constituents of coated electrodes, a classical fibrogenic agent, silica, is present in considerable amounts in electrode coatings. Schuler et al (1962) stated that there is little or no silica in welding fume. This is clearly wrong, large amounts are present (Thrysin et al, 1952) but this is in the amorphous or combined form of SiO_2 rather than the crystalline form (Pantucek, 1972., Buckup, 1977). The latter has long been recognised to cause severe nodular and fibrotic lung disease while amorphous silica has been considered to have very reduced or absent fibrogenic properties.

Vitums et al (1977) have found that prolonged occupational exposure to amorphous silica dust, a product of vaporized crystalline silica, can cause reticular and/or nodular abnormalities on chest radiographs but that despite widespread granulomatous nodules and fibrosis there is no demonstrable restrictive dysfunction. Thus silica exposure does not necessarily explain the cases of fibrosis with dysfunction despite their mixed exposure.

Friede and Rachow (1961) reported the case of an electric arc welder who had worked in poorly ventilated conditions for eleven years. He had severe pulmonary insufficiency due to diffuse pulmonary fibrosis and advanced emphysema and lung function tests showed an obstructive pattern. Lung biopsy confirmed the radiographic diagnosis of fibrosis and emphysema. The alveolar septa were thickened by fibrosis and the alveoli contained macrophages loaded with iron. The interstitial tissues showed diffuse fibrosis and contained iron loaded macrophages. There is no smoking history nor details of other occupations. The coating of the electrode he used contained silica (total 6.1% free (as SiO_2) 3.4%), and the concentration of total particulate fume in the breathing zone was high at 37 mg/m^3 with free silica (as SiO_2) making up 16%. Particle diameter was less than 1 μ.

Kierst et al (1964) examined welders in heavy and shipbuilding industries where breathing zone concentrations of total particulate matter were 19-30 mg/m^3, silica making up 3-9% (the form of silica is not stated). Six welders had radiographic appearance of sidero-silicosis.

The report by Charr (1956) contains little exposure data stating only that there was no known exposure to atmospheres containing silica. Three welders with severe respiratory disturbances were described, the outstanding complaints being dyspnoea and cough. Chest radiography was compatible with diffuse fibrosis and lung biopsy in two cases revealed fibrosis. Charr does not argue that these changes were due solely to iron oxide but suggests that other components of the fume may have acted with the iron to produce fibrosis.

Irmscher et al (1975) showed the co-existence of fibrosis and iron deposits in some lung biopsies from fourteen welders.

Guidotti et al (1978) present the results of light and scanning electron microscopy studies of the lungs of a welder who in life had chest radiograph appearances of marked bilateral micronodular and coarse interstitial pattern diagnosed as pulmonary fibrosis and siderosilicosis. Microscopically there was minimal collagen response around some iron deposits and extensive fibrosis was not associated with intracellular iron accumulation. Several dense, apparently acellular, heavily fibrotic nodules were visible. These had a whorled configuration to their collagen bundles, suggestive of silicotic origin and were not associated with heavy concentrations of iron. Einbrodt et al (1971) disagree stating that there are no indications of a SiO_2 fibrosis and that the cause of the fibrosis is unknown.

There is evidence that in co-existence fibrogenic properties of individual elements and their compounds may be altered. When free silica is found in combination with iron the fibrosing ability of the silica is modified to produce a more non-specific fibrosis which may lead to emphysema. Exposure to nitrogen dioxide at 25 ppm and ferric oxide dust led to diminished pulmonary compliance in dogs after six months (Lewis et al, 1969). Clearance of NO_2 in the upper respiratory tract in dogs is 90% and thus only 10% of the gas, 2.5 ppm would have reached the lower respiratory tract. As 90% of an inhaled dose reaches human alveoli a breathing zone concentration of less than 3 ppm would give an equivalent alveolar dose. The relevance of this evidence to man is not known.

Thus it may be wise to discard the terms arc welders' siderosis and "welders' lung" and use arc welders' pneumoconiosis, simple or complicated. The simple form is analogous to the originally described siderosis, a benign non-fibrotic and potentially reversible condition due to inhalation of iron oxide from welding fumes. The complicated and relatively rare form is a mixed dust pneumoconiosis produced by the inhalation of moderately high concentrations of the mixture of ferrous and non-ferrous and possibly the gaseous elements of welding fume and is characterised by dyspnoea, cough, polycythaemia, and interstitial fibrosis. Rarely there may be co-existing splanchnic siderosis (Carta and Pirastu 1959., Schuler et al, 1962) and increased serum iron levels (Carta and Pirastu, 1959).

Asbestos related disease

Asbestos related parenchymal changes were restricted to the older men who had significant exposure in the days when asbestos dust control was virtually non-existent. Pleural changes, which are at least an indicator of exposure, were much more common. These aspects of welders' health have been fully discussed elsewhere.

5. CONCLUSIONS

1. The vast majority of Dockyard welders have been welders throughout their working lives and have been engaged almost exclusively on manual metal arc welding. A high proportion of those aged 30 and over have had significant occupational exposure to asbestos dust.

2. The prevalence of chronic bronchitis (chronic cough and phlegm) and dyspnoea is not related to duration of exposure to welding pollutants. Only one non-smoker had chronic bronchitis suggesting that tobacco smoking is more likely to be the cause of the measured prevalence in the group than welding.

3. Eighty eight (26.8%) of welders had abnormal lung function patterns with obstruction dominating and those with a positive smoking habit had more than twice the prevalence of non-smokers. The prevalence increases with time as a welder and of course with age. The inability to separate the effects of exposure and age when these relatively small numbers are involved precludes the conclusion that welding causes abnormalities but there is no doubt that smoking is a strong factor. A case control study is required.

4. The prevalence of siderosis was lower than in virtually all other studies and showed no correlation with signs, symptoms nor functional impairment.

5. Many men had had significant exposure to asbestos at work and this is witnessed by the presence of pleural fibrosis in 22.3% and small irregular opacities in 3.3%.

6. Metal fume fever is most common in middle aged men.

7. While working with low hydrogen electrodes men may be affected by morning phlegm.

8. Almost 50% of welders had casual blood pressure of 140/90 mmHg or over the proportion rising to 90.6% in those of 60 years and over.

9. Absence of time relationships with symptoms and other findings could be a survivor population effect.

REFERENCES

AHLMARK, A., and LONNEBERG, B. (1953)
A clinical examination of workers with more than 5 years continuous welding experience.
Nord. Hyg. Tidskr. 34,238.

ANSELINE, P. (1972).
Zinc fume fever.
Med. J. Aust. 2,316.

ANTHONY, J.S., ZAMEL, N., and ALBERMAN, A. (1978).
Abnormalities in pulmonary function after brief exposure to toxic metal fumes.
Can. Med. Assoc. J. 119,6,586.

ANTTI-POIKA, M., HASSI, J., and PYY, L. (1977).
Respiratory diseases in arc welders.
Int. Arch. Occup. Environ. Hlth. 40,3,225.

ATTFIELD, M.D., and ROSS, D.S. (1978).
Radiological abnormalities in electric arc welders.
Br. J. Ind. Med. 35,117.

BARHAD, B., TECULESCU, D., and CRACIUM, O. (1975).
Respiratory symptoms, chronic bronchitis and ventilatory function in shipyard welders.
Int. Arch. Occup. Environ. Hlth. 36,2,137.

BARRIE, H.J., and HARDING, H.E. (1947).
Argyro-siderosis of the lungs of silver finishers.
Br. J. Ind. Med. 4,225.

BRITTON, J.F., and WALSH, E.L. (1940).
Health hazards of electric welding.
J. Ind. Hyg. Toxicol. 22,125.

BRODIE, J. (1943).
Welding fumes and gases - their effects on the health of the worker.
California and Western Medicine 59,1,13.

BUCKUP, H. (1977).
Silicic acid in welding smokers.
IIW Doc VIII - 707-77.

CARTA, G., and PIRASTU, F. (1959).
Raro Caso di Siderosis Splanchnica.
Ann. Radio. Diag. 32,60.

CASANOUVE, P., and SOUDAN, G. (1961).
Considerations sur la pneumoconiose des mineurs de fer.
Arch. Mal. Prof. 22,704.

CASSAN, G. (1972).
Pulmonary siderosis of arc welders: diffuse interstitial and conglomerate fibrosis.
Arch. Mal. Prof. 33,193.

CHARPIN, J. (1965).
Lung siderosis in arc welders.
J. France. Med. Chir. Thor. 19,197.

CHARR, R. (1953).
Respiratory disorders among welders.
JAMA 152,1520.

CHARR, R. (1955).
Respiratory disorders among welders.
Amer. Rev. Tuber. 71.877.

CHARR, R. (1956).
Pulmonary changes in welders - A report of three cases.
Ann. Int. Med. 44,806.

CHMIELEWSKI, J., JAREMIN, B., BARTNICKI, C., and KONIECSKA, R. (1974).
Examination of the state of health of welders exposed to zinc oxide.
Bull. Inst. Mar. Med. Gdansk. 25,53.

COHEN, D. (1973).
Ferromagnetic contamination in the lungs and other organs of the human body.
Science, 180,745.

DeKRETSER, A.J., EVANS, W.D., and WALDRON, H.D. (1964).
Carbon monoxide hazard in the CO_2 arc welding hazard.
Ann. Occup. Med. 7,253.

DEPARTMENT OF EMPLOYMENT (1972).
Chief Employment Medical Adviser's Notes of Guidance. 50. Welding.

DOBRZYNSKI, W. (1974).
Chronic non specific disease of the respiratory system among electric welders.
Roczn. pom Akad. Med. Swierczewskiego, Suppl. 10.265.

DOIG, A.T. and DUGUID, L.N. (1951).
The Health of Welders, HMSO London.

DOIG, A.T., and McLAUGHLIN, A.I.G. (1936).
X-ray appearances of the lungs of electric arc welders.
Lancet. 1,771.

DOIG, A.T., and McLAUGHLIN, A.I.G. (1948).
Clearing of x-ray shadows in welders' siderosis.
Lancet. 1,789.

DONOSO, H., SEGURA, E., VALLEJOS, M.E., and LORONO, R. (1974).
Siderosis de los soldadores al arco (Arc welders siderosis)
Rev. Med. Chi. 102,3,202.

DRESSEN, W.C., BRINTON, H.P., KEENAN, R.G., THOMAS, T.R., PLACE, E.H., and FULLER, J.E. (1947).
Health of Arc Welders in Steel Ship Construction.
Public Health Bulletin No. 298 Federal Security Agency.
US Public Health Service. United States Government Printing Office, Washington.

DRINKER, P., and NELSON, K.W. (1944).
Welding Fumes in Steel Fabrication.
Texas Journal of Medicine, XL.275-278.

EINBRODT, H.J., MAASS, W., JOSTEN, H.G., and STECHER, W. (1971).
Examination of lung changes in arc welders.
Off. Gesundh-Wes, 33,286-299.

ENGEL, H. (1934).
Zinc
in Occupational Health, Noicclerc and Fenetrier, Lyons, 2,1277.

ENZER, N., and SANDER, O.A. (1938).
Chronic lung changes in electric arc welders.
J. Ind. Hyg. Toxicol 20,333.

ENZER, N., SIMONSON, E., and EVANS, A.M. (1945).
Clinical, Physiological Observations on Welders with Pulmonary Siderosis and Foundry men with nodular uncomplicated Silicosis.
J. Ind. Hyg. Toxicol. 27,147.

EVANS, M.J., INGLE, J., MOLYNEUX, M.K., SHARP, G.T.H., and SWAIN, J. (1979).
An occupational hygiene study of a controlled welding task using a general purpose rutile electrode.
Ann. Occup. Hyg. Vol. 22,1.

FISHBURN, C.W., and ZENZ, C. (1969).
Metal fume fever. A report of a case.
J. Occup. Med. 11,142.

FOGH, A., FROST, J., and GEORG, J. (1969).
Respiratory symptoms and pulmonary function in welders.
Ann. Occup. Hyg. 12,4,213.

FOGH, A., FROST, J., and GEORG, J. (1971).
Report of a Danish investigation into the health and working environment of arc welders.
IIW Doc 440-71.

FRIEDE, E., and RACHOW, D.O. (1961).
Symptomatic pulmonary disease in arc welders.
Ann. Inter. Med. 54,121.

GARNUSZEWSKI, Z., and DOBRZYNSKI, W. (1967).
Regression of Pulmonary Radiological Changes in Dockyard Welders after Cessation or Decrease of Exposure to Welding Fumes.
Polish Med. J. 6,3,610.

GLASS, W.I. (1970).
Mercury fume fever.
NZ Med. J. 71,297.

GROHR, J.A. (1944).
Benign pulmonary changes in arc welders.
Ind. Med. 13,8,598.

HAGLIND, O. (1957).
Lung changes in electric welders.
Proceedings of the XII International Congress on Occupational Health III: 169-171.

HAMILTON, A. (1925).
in Industrial Poisons in the United States, McMillan, New York, 276-290.
cited by Ross, 1974b.

AMLIN, L.E. (1959).
iderosis: additional observations over a period of 8 years on 69 foundry leaning room employees.
OM 1,79.

AMLIN, L., and WEBBER, H.J. (1950).
iderosis: clinical, roentgenological and industrial hygiene study of oundry cleaning employees.
nd. Med. 19.4.

IARDING, H.E. (1945).
Radiographic and histological appearances of the rat lung after intratracheal injection of rough (Fe_2O_3).
Br. J. Ind. Med. 2,32.

HARDING, H.E. (1948).
Fibrosis in the lungs of a silver finisher.
Br. J. Ind. Med. 5,70.

HARDING, H.E., GROUT, J.L.A., and LLOYD DAVIES, T.A. (1947).
The experimental production of x-ray shadows in the lungs by inhalation of industrial dusts. 1 Iron Oxide.
Br. J. Ind. Med. 4,223.

HARDING, H.E., McLAUGHLIN, A.I.G., and DOIG, A.T. (1958).
Clinical, radiological and pathological studies of the lungs of electric arc and oxyacetylene welders.
Lancet 2,294.

HOSCHEK, R. (1970).
Health risks in gas and arc welding.
Mod. Unfallverhutung, 15. 30-35.
read in English translation.

HUNNICUTT, T.N., CRACOVANER, D.J., and MYLES, J.T. (1964).
Spirometric measurement in welders.
Arch. Environ. Health. 8,5,661.

IRMSCHER, G., BECK, B., AHLENDORF, W., ANSPACH, M., KONETZKE, G., LUDWIG, V., and STURN, W. (1975).
Experience in expert assessment of dubious lung fibrons from effect of welding fumes.
Z ges. Hyg. 21,562.

JAREMIN, B., CHMICLEWSKI, J., and BARTNICKI, C. (1974).
Zinc fever among shipbuilding industry employees.
Roczn. pom. Akad. Med. Swierczewskeigo 10.311-319.
(read in English translation of abstract).

JONES, J.G., and WARNER, C.G. (1972).
Chronic exposure to iron oxide and nickel oxide fumes of metal dressers in a steelworks.
Br. J. Ind. Med. 29,169.

KADEFORS, R., PETERSEN, I., and HERBERTS, P. (1976).
Muscular reaction to welding work: an electromyographic investigation.
Ergonomics 19,5,543.

KALLIOMAKI, P-L., KARP, P., KATILA, T., MAKIPAA, P., SAAR, P., and TOSSAVAINEK, A. (1976).
Magnestic measurements of pulmonary contamination.
Scand. J. Work. Environ. Health. 4,232.

KALLIOMAKI, P-L., Keskinen, H., and VIRTAMO, M. (1977).
A case report of occupational asthma in a stainless steel welder.
Given at the Annual Assembly of the International Institute of Welding.
Denmark, IIW Doc 755-77.

KALLIOMAKI, P-L., KARHONEN, O., VAARANAN, V., KALLIOMAKI, K., and KOPONEN, M. (1978a).
Lung retention and clearance of shipyard arc welders.
Int. Arch. Occup. Environ. Health 42,83.

KALLIOMAKI, K., KALLIOMAKI, P-L., KELHA, V., SORTII, V., and VAARANEN,V. (1978b).
Measurement of lung contamination among mild steel and stainlees steel welders.
Presented at International Institute of Welding, 31 Annual Assembly, Dublin.
IIW Doc VIII-788-78.

KALLIOMAKI, P-L., HUUSKONEN, M., KARHONEN, O., MATTSON, T., SORTII, V., and VAARANEN, V. (1978c).
Lung contamination among workers exposed to dust with an iron content.
Presented at XIX International Congress on Occupational Health, Dubrovnik, Yugoslavia, Sept 25-30.

KIERST, W., USELIS, J., GRACZYK, M., and KRYNICK, A. (1964).
Pulmonary changes in shipyard arc welders.
Bull. Inst. Mar. Med. Gdansk. 15,3/4,149.

KILLICK, E.M. (1938).
Br. J. Radiol. 11,401.

KLEINFELD, M., MESSITS, J., KOOYMAN, O., and SHAPIRO, J. (1969).
Welders' Siderosis.
Arch. Environ. Health. 19,70.

KUJAWSAK, A., MAREK, K., DOMAGALIK, L., and KALEMBA, K. (1975).
Evolution of radiological changes and functional disturbances in arc welders' pneumoconiosis.
Med. Pracy. 26,4,307.
read in English translation of abstract.

LEWIS, T.R., CAMPBELL, K.I. and VAUGHAN, T.R. (1969).
Effects on canine pulmonary function via induced nitrogen dioxide impairment, particulate interaction and subsequent SO_x.
Arch. Environ. Health. 18,596.

LUCCIONI, R., CHARPIN, J., and MOSINGER, M. (1966).
Pulmonary siderosis in arc welders.
Arch. Mal. Prof. 27,803.

McCORD, C.P. (1960).
Metal Fume Fever as an Immunological Disease.
Ind. Med. Surg. 12,101.

McLAUGHLIN, A.I.G., GROUT, J.L.A., BARRIE, H.J., and HARDING, H.E. (1945).
Iron oxide dust and the lungs of silver finishers.
Lancet. 248,337.

MAGNUSSON, E.J. (1974).
The problems of fumes in welding.
Svetsaren, a welding review 3,1.

MALIK, E., and ULRICH, L. (1975).
Roentgenologic changes in the lungs of electrowelders after several years exposure.
Pracov Lek 27,9.314-7
read in English translation.

MANN, B.T., and LECUTIER, E.R. (1957).
Arc welders' lung.
Br. Med. J. 2,921.

MAYER, E., and RAPPAPORT, I. (1954).
Industrial diseases of the lung, in Non-tuberculous diseases of the chest,
Charles C Thomas, Springfield, III. 755.

MEO, G., SULLOTTO, F., and LACOUANITI, A. (1966).
Damage to respiratory function in welders with lung siderosis.
Folia Med (Napoli) 49,506.

MORGAN, W.K.C. (1962).
Arc welder's lung complicated by conglomeration.
Am. Rev. Resp. Dis. 85,570.

MORGAN, W.K.C., and KERR, H.D. (1963).
Pathologic and physiologic studies of welders' siderosis.
Ann. Int. Med. 58,2,293.

MOUTON, N. (1976).
Study of three cases of pulmonary siderosis in arc welders.
Arch. Mal. Prof. 37,413.

OHMOTO, M., ISHIMI, A., DOI, K., NUKADA, A., AKASHI, S., MORI, T., and MATSUDA, A. (1974).
Toxicity of electric arc welding fumes; Experimental studies on welders' fever.
Jpn, J. Ind. Health 16,103.

OUW, K.M., JONES, R., YOUNG, I., REECE, R., SHANDAR, A., and HAYES, M (1977).
Welding fumes, their effect on man.
IIW Doc. VII-713-77.

OYANGUREN, H., HADDAD, R., and MAASS, H. (1958).
Stannosis I Environmental and experimental studies.
Ind. Med. 27,427.

PANTUCEK, M. (1972).
Influence of filler materials on air contamination in manual electric arc welding.
J. Am. Ind. Hyg. Ass. 32,10,687.

PAPP, J.P. (1968).
Metal fume fever case report.
Postgrad Med 43,160.

PIERCE, J.O. (1972).
Metal fume fever, in Occ Health and Safety, 110, Geneva, 867.

PETERS, J.M., MURPHY, R.L.H., FERRIS, B.G., BURGESS, W.A., RANADIVE, M.V., and PERDERGRASS, H.P. (1973).
Pulmonary function in shipyard welders.
Arch. Environ. Health. 26,1,28.

PETERSEN, I., KADEFORS, R., and PERSSON, J. (1976).
Neurophysiologic studies of welders in shipbuilding work.
Environ. Res. 11,226.

PETIT, D.W. (1943).
Some respiratory hazards of welding.
A review of recent literature.
Standard Medical Bulletin, 1,5,136.

PIKULSKAYA, A.F., and GULKO, S.N. (1975).
External respiration and drainage function of the bronchi in electric welders.
Vrach Delo 1,127.
read in English translation of abstract.

ROHRS, C.L. (1957).
Metal fume fever from inhaling iron oxide.
Arch. Inter. Med. 100,44.

ROSS, D.S. (1974).
Welders' metal fume fever.
J. Soc. Occup. Med. 24,125.

ROSSITER, C.E., RIVERS, D., BERGMAN, I., CASSWELL, C., and NAGELSCHMIDT, G. (1965).
Dust content, radiology and pathology in simple pneumoconiosis of coal miners.
in Inhaled particles and vapours II, Pergamon Press, Oxford, p 419.

SADOUL, P. (1972).
Pulmonary siderosis
in Encyclopaedia of Occupational Health and Safety.
International Labour Organisation, Geneva.

SANDER, O.A. (1944).
Further observations on lung changes in electric welders.
J. Ind. Hyg. 26,80.

SAYER, R.R. (1938).
Metal fume fever and its prevention.
Public Health Rep. Washington, 53,1080.

SCHIOTZ, E.H. (1945).
Welding regarded from the medical point of view.
Act. Med. Scand. 121,537.

SCHULER, P., MATURANA, V., CRUZ, E., GUIJON, C., VASQUEZ, A., VALENZUELA, A., and SILVA, R. (1962).
Arc welders' pulmonary siderosis.
J. Occup. Med. 4,353.

SEVCIK, M., CHALUPA, B., KLHUFKOVA, E., and HRAZDIRA, C.L. (1960).
Z61. Arbeitsmed. 10.77.
cited by Hunnicutt, 1964.

SJOGREN, B. (1977).
Reported by Gerhardsson, G in Workshop on Welding International Symposium on the Control of Air Pollution in the Working Environment. Stockholm, September, p255-258.

SLEPICKA, J., KADLEC, K., TESAR, Z., SKODA, V., MIREJOVSKY, P. (1970).
Problem of arc welding pneumoconiosis.
Int. Arch. Arbeitsmed. 27,257.

SLEPICKA, J., TESAR, Z., and MIREJOVSKY, P. (1974).
The effect of electric arc welding upon the respiratory tract of welders.
Pracov Lek 26. 295-302.
read in English translation.

SPACILOVA, M., and KOVAL, Z. (1975).
Pulmonary x-ray and function findings in electric arc welders.
Int. Arch. Arbeitsmed. 34,3,231.

STANESCU, D.C. PILAT, L., GAVRILESCU, N., TECULESCU, P.B. and CRISTESCU, I. (1967).
Aspects of Pulmonary Mechanics in arc welders' siderosis.
Br. J. Ind. Med. 24,143.

STOBER, W., EINBRIDT, J., and KLOSTERKOTTER, W. (1965).
Quantitative studies of dust retention in animal and hyman lungs after chronic inhalation.
in Inhaled particles and vapours II, Pergamon Press, Oxford, 409.

THACKRAH, C.T. (1832).
The effects of Arts, Trades and Professions and of Civic States and Habits of Living on Health and Longevity. London, Langman, 101.

THRYSIN, E., GERHARDSSON, G., and FORSSMAN, S. (1952).
Fumes and gases in arc welding.
Arch. Ind. Hyg. Occup. Med. 6,5,381.

VILES, F.J. (1945).
Control of welding fumes.
Ind. Med. 14,71.

VITUMS, V.C., NILES, N.R., BORMAN, J.O., and LOWRY, R.D. (1977).
Pulmonary fibrosis from amorphous silica dust.
Arch. Environ. Health. 62.

VORWARD, A.J., PRATT, P.C., DURKAN, T.M., DELAHANT, A.B., and BAILEY, D.A. (1950)
An experimental study of the pulmonary reaction following inhalation of dust generated by cleaning room operations.
Ind. Med. 19.22.

WILLIAMS, F.L. (1935).
Electric Welding II. An acute fatal pneumonia following electric welding of galvanised iron in a confined space.
J. Ind. Hyg. Toxicol 17,129.

ZENKER, F.A. (1967).
Uber staubinhalationskrankheiten der lungen.
Deutsches. Arch. Klin. Med. 2,116.

TABLE C1. Absolute and relative age frequency distribution of welders

	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All ages
Number of men	44	36	107	109	32	328
% total	13.4	11.0	32.6	33.2	9.8	100

TABLE C2. Absolute and relative frequency distribution of time (years) employed as a welder

	Time (years)					
	Under 10	10-19	20-29	30-39	40 and over	All
Number of men	18	61	135	82	32	328
% total	5.5	18.6	41.2	25.0	9.8	100

TABLE C3. Absolute and relative frequency distribution of time (years) since first employed as a welder

	Time (years)					
	Under 10	10-19	20-29	30-39	40 and over	All
Number of men	18	57	133	85	35	328
% total	5.5	17.4	40.5	25.9	10.7	100

TABLE C4. Number and percentage of welders employed in the main welding processes used in the Dockyards

Process		Frequency of use of welding process			
		Mainly	Occasion-ally	Only in training	Not at all
Manual metal arc	No. %	314 95.7	13 4.0	0 0.0	1 0.3
Tungsten inert gas	No. %	8 2.4	95 29.0	35 10.7	190 57.9
Metal inert gas	No. %	5 1.5	131 39.9	39 11.9	153 46.6
Oxyacetylene	No. %	1 0.3	21 6.4	8 2.4	298 90.9

TABLE C5. Number (and percentage) in each age group of welders employed mainly in each welding process

Welding process	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All ages
Manual metal arc	43 (97.7)	35 (97.2)	101 (94.4)	105 (96.3)	30 (93.8)	314 (95.7)
Tungsten inert gas	1 (2.3)	0 (0.0)	2 (1.9)	3 (2.8)	2 (6.2)	8 (2.4)
Metal inert gas	0 (0.0)	1 (2.8)	4 (3.7)	0 (0.0)	0 (0.0)	5 (1.5)
Oxyacetylene	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.9)	0 (0.0)	1 (0.3)

TABLE C6. Number (and percentage) in each age group with history of occupational exposure to asbestos

Occupational situation of exposure	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All ages
Use during welding	15 (34.1)	30 (83.3)	96 (89.7)	97 (89.3)	29 (90.6)	267 (81.4)
Personally lagging or delagging	4 (9.1)	4 (11.1)	19 (17.8)	24 (22.0)	4 (12.5)	55 (16.8)
Exposure to limpet spraying	2 (4.5)	11 (30.6)	71 (66.4)	70 (64.2)	22 (68.7)	176 (53.7)
Exposure to other asbestos work	9 (20.5)	21 (58.3)	54 (50.5)	64 (58.7)	16 (50.0)	164 (50.0)

TABLE C7. Number (and percentage) in each age group of welders in each smoking habit category

Smoking habit	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All ages
Smoker	18(40.9)	18(50.0)	64(59.8)	47(43.1)	18(56.2)	165(50.3)
Ex-smoker	12(27.3)	8(22.2)	17(15.9)	41(37.6)	7(21.9)	85(25.9)
Non-smoker	14(31.8)	19(27.8)	26(24.3)	21(19.3)	7(21.9)	75(23.8)

TABLE C8. Number (and percentage) of welders who reported significant chest disease, injury or operation during their working lives related to time employed as a welder

Chest condition	Time (years) as a welder					
	Under 10	10-19	20-29	30-39	40 and over	All
Injury or operation	1(5.5)	1(1.6)	10(7.4)	6(7.4)	3(9.4)	21(6.4)
Bronchitis	2(11.1)	18(29.5)	46(34.1)	18(21.9)	12(37.5)	96(29.3)
Tuberculosis	0(0.0)	1(1.6)	4(3.0)	2(4.8)	0(0.0)	7(2.1)
Pleurisy	1(5.5)	7(11.4)	19(14.1)	11(13.4)	3(9.4)	41(12.5)
Pneumonia	1(5.5)	8(13.1)	22(16.3)	9 (11.0)	4(12.5)	44(13.4)

TABLE C9. Number (and percentage) of welders who reported respiratory symptoms related to time employed as a welder

Symptom	Time (years) as a welder					
	Under 10	10-19	20-29	30-39	40 and over	All
Chronic cough	0(0.0)	9(14.7)	24(17.8)	12(14.6)	8(25.0)	53(16.2)
Chronic phlegm	4(22.2)	11(18.0)	27(20.0)	15(18.3)	5(15.6)	62(18.9)
Cough and phlegm	0(0.0)	5(8.2)	16(11.9)	9(11.0)	3(9.3)	33(10.1)
Dyspnoea grade 2	1(5.5)	6(9.8)	25(18.5)	18(21.9)	5(15.6)	55(16.8)
" " 3	0(0.0)	1(1.6)	6(4.4)	4(4.9)	1(3.1)	12(3.7)
" " 4	0(0.0)	0(0.0)	0(0.0)	1(1.2)	0(0.0)	1(0.3)
" " 5	0(0.0)	0(0.0)	1(0.7)	0(0.0)	0(0.0)	1(0.3)
Dyspnoea all grades	1(5.5)	7(4.5)	32(23.7)	23(17.0)	6(18.7)	69(21.0)

TABLE C10. Number (and percentage) of welders in whom listed signs were found related to time as a welder

Clinical signs	Time (years) as a welder					
	Under 10	10-19	20-29	30-39	40 and over	All
Finger clubbing				1(1.2)		1(0.3)
Cyanosis						0(0.0)
Tracheal deviation						0(0.0)
Percussion dullness		1(1.6)				1(0.3)
Persistent rales	1(5.5)	4(6.5)	6(4.4)	10(12.0)	4(12.5)	18(5.5)
Rhonchii	1(5.5)	2(3.3)	5(6.1)	7(8.5)	3(9.4)	22(6.7)
Pleural rub or creak			1(1.2)		1(3.1)	2(0.6)
Local tenderness	1(5.5)	1(1.6)				2(0.6)

TABLE C11. Percentage (and number) or welders in each age group with blood pressure of 140/90 mmHg or more.

	Age (years)					
	<29	30-39	40-49	50-59	60-	All
Percent (and number)	8.1(4)	25.0(9)	51.4(55)	60.5(66)	90.6(29)	49.7(163)

TABLE C12. Number (and percentage) of welders who reported metal fume fever related to time employed as a welder

Metal fume fever (MFF)	Time (years) as a welder					
	Under 10	10-19	20-29	30-39	40 and over	All
In previous year	1(5.5)	7(11.5)	18(13.3)	11(13.4)		37(11.3)
Not in previous year but at other times	9(50.0)	35(57.4)	75(55.5)	47(57.3)	18(56.3)	184(56.1)
Total with MFF	10(55.5)	42(68.9)	93(68.8)	58(70.7)	18(56.3)	221(67.4)

ABLE C13. Percentage (and number) of welders in each "time as welder" and smoking habit category with obstructive, restrictive and mixed obstructive and restrictive abnormal lung function patterns (FEV_1 and FVC

a. Obstructive

Smoking habit	Time as welder (years)					
	Under 10	10-19	20-29	30-39	40 and over	All
Smoker	12.5(1)	11.1(3)	10.8(8)	19.5(8)	26.7(4)	14.5(24)
Ex-smoker		12.5(2)	6.5(2)	8.3(2)	15.3(2)	9.4(8)
Non-smoker		5.5(1)	20.0(6)	11.8(2)	25.0(1)	12.8(10)
All	5.5(1)	9.8(6)	11.9(16)	14.6(12)	21.9(7)	12.8(42)

b. Restrictive

Smoking habit	Time as welder (years)					
	Under 10	10-19	20-29	30-39	40 and over	All
Smoker	12.5(1)	3.7(1)	6.7(5)	17.0(7)	6.7(1)	9.1(15)
Ex-smoker				20.8(5)	23.0(3)	9.4(8)
Non-smoker	11.1(1)		3.3(1)	5.9(1)	25.0(1)	5.1(4)
All	11.1(2)	1.6(1)	4.4(6)	15.9(13)	15.6(5)	8.2(27)

c. Mixed

Smoking habit	Time as welder (years)					
	Under 10	10-19	20-29	30-39	40 and over	All
Smoker		3.7(1)	9.5(7)	4.9(2)	13.3(2)	7.3(12)
Ex-smoker			9.7(3)		15.4(2)	5.9(5)
Non-smoker				(2)		2.6(2)
All		1.6(1)	7.4(10)	11.8(4)	12.5(4)	5.8(19)

d. All

SMOKING habit	Time as welder (years)					
	Under 10	10-19	20-29	30-39	40 and over	All
Smoker	25.0(2)	18.5(5)	27.0(20)	41.5(17)	46.7(7)	30.9(51)
Ex-smoker		12.5(2)	16.1(5)	29.2(7)	53.8(7)	24.7(21)
Non-smoker	11.1(1)	5.5(1)	23.3(7)	29.4(5)	50.0(2)	20.5(16)
All	16.7(3)	13.1(8)	23.7(32)	35.4(29)	50.0(16)	26.8(88)

TABLE C14. Individual reader's and "agreed" classification for small opacities RR, RI.

Source of radiograph classification	ILO 1979 Classification for small opacities RR, RI					Radiograph not available
	%	0/1	1/0	1/1	1/2	
Reader 1	285(86.9)	16(4.9)	2(0.6)	9(2.7)	5(1.5)	11(3.4)
Reader 2	271(82.6)	16(4.9)	17(5.2)	12(3.7)	1(0.3)	11(3.4)
Reader 3	220(67.1)	61(18.6)	26(7.9)	7(2.1)	3(0.9)	11(3.4)
"Agreed"	274(83.5)	25(7.6)	11(3.4)	7(2.1)		11(3.4)

TABLE C15. Welders with "agreed" radiographic classification 1/0 or more for RR, R1 small opacities by time spent as a welder

Radiographic classification	Time (years) as a welder					
	Under 10	10-19	20-29	30-39	40 and over	All ages
1/0			3	8	0	11(3.4)
1/1		1	1	4	1	7(2.1)
1/2						0(0.0)
All 1/0 and over	0(0.0)	1(1.6)	4(3.0)	12(14.6)	1(3.1)	18(5.5)

TABLE C16. Individual reader's and "agreed" radiographic classification for small opacities II, IR

Source of radiograph classification	ILO 1979 Classification for small opacities II, IR					Radiograph not available
	%	0/1	1/0	1/1	1/2	
Reader 1	285(86.9)	16(4.9)	5(1.5)	9(2.7)	2(0.6)	11(3.4)
Reader 2	295(89.9)	4(1.2)	9(2.7)	7(2.1)	2(0.6)	11(3.4)
Reader 3	264(80.5)	18(5.5)	20(6.1)	10(3.0)	5(1.5)	11(3.4)
"Agreed"	295(89.9)	11(3.4)	5(1.5)	4(1.2)	2(0.6)	11(3.4)

TABLE C17. Welders with "agreed" radiographic score 1/0 or more for II, IR small opacities by time spent as a welder

Radiographic classification	Time (years) as a welder					
	Under 10	10-19	20-29	30-39	40 and over	All
1/0			3(2.2)	1(1.2)	1(3.1)	5(1.5)
1/1		1(1.6)	2(1.5)	1(1.2)		4(1.2)
1/2			2(1.5)			2(0.6)
All 1/0 and over	0	1(1.6)	7(5.2)	2(2.4)	1(3.1)	11(3.3)

TABLE C18. Individual readers' and "agreed" decision on presence of pleural fibrosis

Source of radiographic classification	Pleural thickening present		Radiograph not available
	Without calcification	With calcification	
Reader 1	81(24.7)	21(6.4)	11(3.4)
Reader 2	69(21.0)	22(6.7)	11(3.4)
Reader 3	64(19.5)	20(6.1)	11(3.4)
"Agreed"	73(22.3)	21(6.4)	11(3.4)

R (Clin) MEDICAL IN CONFIDENCE

Cols

| W | D | 6 | | 1-3

...y No. | | | | | National Insurance No. | | | | | | | | | | 4-16

...me 17-19

... Names ....

Address ....

....

...ard Number ....   Survey x-ray number | | | | | | 20-24

...onal Health Service Number | | | | | | | | | | | | | | | | | 25-40

... of Birth D M Y 41-46

... Name ....

Address ....

....

... of interview 47-52

...the actual wording of each question. If YES, tick appropriate box.
...in doubt record NO by leaving box blank.

...MBLE: "I am going to ask you some simple questions about your chest.
Please try to answer the questions wherever possible as YES or NO".

... ILLNESSES

Have you ever had

	Age	Yes	
a. An injury or operation affecting your chest?	...	☐	53
b. Pleurisy?	...	☐	54
c. Pulmonary Tuberculosis?	...	☐	55
d. Bronchitis?	...	☐	56
e. Pneumonia?	...	☐	57
f. Any other serious chest illness? eg Asthma	...	☐	58

...H

a. Do you usually cough during the day (or at night when on night-work)? If NO, go to 3. ☐ 59

b. Do you cough like this on most days for as much as 3 months each year? ☐ 60

...M

a. Do you usually bring up any phlegm from your chest first thing in the morning in the winter? If NO, go to 3c. ☐ 61

b. Do you bring up phlegm like this on most days for as much as three months each year? ☐ 62

c. Have you ever coughed up any blood? If NO, go to 4. ☐ 63

d. When was this? Record each year of occurrence ....

4. In the winter

Cols

a. Are you ever troubled by shortness of breath when hurrying on the level or walking up a slight hill? If NO, Grade 1. If YES, proceed to next question.

b. Do you get short of breath walking with other people at an ordinary pace on the level? If NO, Grade 2. If YES proceed to next question.

c. Do you have to stop for breath when walking at your own pace on the level? If NO, Grade 3. If YES, proceed to next question.

d. Are you short of breath on washing or dressing? If NO, Grade 4. If YES, Grade 5. — Grade 1-5 [ ] 64

TOBACCO SMOKING (Tick box if YES)

8. a. Have you ever smoked? (This means as much as one cigarette or one small cigar a day, or one large cigar a week, or one ounce of tobacco a month for as long as a year). If NO, go to 10. — [ ] 65

b. Do you smoke at present? — [ ] 66

c. Have you given up smoking in the last month? — [ ] 67

d. How old were you when you started smoking regularly? — Age [ ][ ] 68-69

e. How many manufactured cigarettes do/did you usually smoke per day including the weekends? — Number [ ][ ] 70-71

f. How much tobacco do/did you usually smoke per day including the week-ends in hand-rolled cigarettes? (Ozs p wk x 4 = gms per day) — [ ][ ] 72-73

g. How much pipe tobacco do/did you usually smoke per week including the week-ends? (Ozs p wk x 4 = gms per day) — gms [ ][ ] 74-75

h. How many small cigars do/did you usually smoke per day including the week-ends? — Number [ ][ ] 76-77

i. How many large cigars do/did you usually smoke per week? — Number [ ][ ] 78-79

EX SMOKERS ONLY

9. How old were you when you last gave us smoking? — Age [ ][ ] 80-81

CHEST PAIN

10. a. Have you ever had any pain or discomfort in your chest? If NO go to 11 — [ ] 82

b. Do you get it when you walk uphill or hurry? — [ ] 83

c. Do you get it when you walk at ordinary pace on the level? If NO, go to 11. — [ ] 84

d. What do you do if you get while you are walking? Stop or slow down = Y ie tick; Carry on = N ie blank — [ ] 85

Record YES if subject carries on after taking Nitroglycerine (Trinitrin)

e. If you stand still what happens to it? Relieved = Y ie tick; Not relieved = N ie blank — [ ] 86

f. If relieved - how soon? 10 minutes or less = Y ie tick; More than 10 minutes = N ie blank — [ ] 87

11. OCCUPATIONAL HISTORY

Age	Employees Name	Job	Job Code	Start Year	Finish Year	Cols
						88-93
						94-99
						100-105
						106-111
						112-117
						118-123
						124-129
						130-135
						136-141
						142-147

Tick box when answer is YES

Do you or did you weld in the normal course of your work? (If YES go to question 14) — 148

Are you or were you exposed to welding fumes in the course of your work? — 149

How many years have you been welding or otherwise exposed to welding fumes? — 150-151

Those who have welded or still weld only

What type of welding do you usually do?

	Occasionally	Yrs	Mainly	
a. Metal arc (stick) welding		....		152-153
b. Tungsten inert gas welding (T16)		....		154-155
c. Metal inert gas welcing (M16)		....		156-157
d. Oxyacetylene		....		158-159
e. Other		....		160-161

Have you had ray burn in the last year? If NO, go to 21. — 162

How many times — 163-164

Which parts of your body, including your hands and feet, were affected? — Code — 165-168

....

....

How many times was it bad enough for you to go to your doctor or the Dockyard Surgery? — 169

How many times were you off work with it? — 170

Cols

21. Have you had arc eye (flash) in the past year? If NO go to 25. 171

22. How many times? 172-173

23. How many times was it bad enough for you to go to your doctor or to the Dockyard Surgery? 174-175

24. How many times were you off work with it? 176-177

25. On what parts of your body including your limbs and face do you get hot metal or slag burns including small burns? ....

.... Code 178-181

26. Have you ever had metal fume fever in the last year? 182

27. If YES when and in what circumstances? ....

.... Code 183-186

28. How many times was it bad enough for you to see your own doctor or the Dockyard Surgery? 187

29. How many times were you off work with it? 188

ASBESTOS EXPOSURE

30. Have you used asbestos cloth in preheating or to protect yourself and the work? 189

31. Have you done any delagging or lagging or other work with asbestos - not just near others working with asbestos 190

Type? ....

When? ....

32. Have you worked near others working with asbestos? 191

a. Limpet spraying 192

If YES, type of ships and approximate dates ☐☐ to ☐☐ 193-196

b. Other asbestos work. 197

Type of work? 198-199

....

Approximate dates .... ☐☐ to ☐☐ 200-

Items of protective clothing usually worn:

		Cols
Head band welding visor/shield	☐	204
Hand shield	☐	205
Dark glasses	☐	206
Dark goggles	☐	207
Safety glasses	☐	208
Leather cap	☐	209
Cloth cap	☐	210
Sweat rag	☐	211
Leather shoulder jacket (to chest level)	☐	212
Leather half jacket (to waist level)	☐	213
Leather full length jacket (hip level)	☐	214
Arm sleeves	☐	215
Short apron	☐	216
Long apron	☐	217
Long apron with splits down front and tied behind	☐	218
Spats	☐	219
Safety shoes (steel toe caps)	☐	220
Safety boots (steel toe caps)	☐	221
Gloves	☐	222
Gauntlets	☐	223
Respirator	☐	224

4. Ordinary clothing usually worn at work

1 Vest	☐	225
2 Vests	☐	226
1 Shirt	☐	227
2 Shirts	☐	228
1 Pullover	☐	229
2 Pullovers	☐	230
1 Pair trousers	☐	231
2 Pairs trousers	☐	232
1 Pair socks	☐	233
2 Pairs socks	☐	234
Boiler suit	☐	235
Ordinary shoes	☐	236
Ordinary boots	☐	237
Wellington boots	☐	238
Any other items?	☐	239
....	☐	240
....	☐	241

5. Ordinary glasses at work? .... ☐ 242

6. Contact lenses at work? .... ☐ 243

General

		Cols
BP		244-249
√= Present	Clubbing	250
	Cyanosis	251
	Trachea N = Normal Y = Abnormal: Note below	252
	Percussion N = Normal Y = Abnormal: Note below	253
	Rales	254
	Persistent rales	255
	Rhonchi	256
	Pleural rub	257
	Other abnormalities - if YES, describe	258

LUNG FUNCTION ASSESSMENT AT CLINICAL EXAMINATION

		Actual	Predicted	Cols
Operator Code			FV Resp	259-260
Standing height (socks)			Cms	261-263
Weight (shirt and trousers)				264-266
FEV				267-272
FVC				273-278
FEV/FVC%				279-282
RV				283-288
TLC				289-294
RV%				295-298
TF				299-304
Mixing Index				305-307
Best curve first: MEF 50% VC				308-316
Best curve first: MEF 25% VC				317-325

SECTION D

A CLINICAL, RADIOLOGICAL AND PULMONARY FUNCTION CASE-CONTROL STUDY OF ONE HUNDRED AND THIRTY FIVE DOCKYARD WELDERS AGED 45 YEARS AND OVER

Summary

A random sample of 135 of the welders employed at three of Her Majesty's Dockyards aged 45 years and over who had accepted an invitation to have medical examinations was drawn and the welders matched for sex, age, smoking habit and potential exposure to asbestos dust at work with 135 Dockyard craftsmen who had never been welders and who should have had no significant exposure to welding fumes and gases.

Standardised clinical interviews and examinations, full size PA chest radiographs and a range of pulmonary function tests were carried out. The radiographs were read by three expert readers working independently and the "agreed" reading of at least two was used for analysis. Results of spirometry were used to allocate each man to normal, obstructive, restrictive or mixed classes of lung function pattern using the method described by Hunnicutt et al (1964). The lung function results of welders and controls were compared using linear regression analysis.

It is concluded that there is no convincing evidence that prolonged exposure of this group of welders to welding fumes and gases in HM Dockyards has caused significant clinical abnormality nor any serious impairment of pulmonary function in the welders when compared to the controls. However, there is a slight suspicion that this exposure may cause obstructive airway changes which are not manifested by any dramatic overt excess of ill-health.

1. INTRODUCTION

If exposure to the fumes and gases arising from welding processes used in the Dockyards is causally related to respiratory disease an excess of that type of disease should be demonstrated when welders are compared to other men working in the Yards who are not regularly exposed to these pollutants. Age, smoking habit and exposure to asbestos must be taken into account in such a comparison. In this study welders with long exposure to the pollutants have been paired on a one-to-one basis with men in the other Dockyard craft groups (same social class), of the same age (+/- one year), smoking habit and potential exposure to asbestos but who should have had no significant exposure to welding on a continuing basis.

2. MATERIAL AND METHODS

2.1 Cases and controls

In Part 1 of this study (INM Report 29/82) 328 of the 368 welders employed at HM Dockyards Devonport,Portsmouth and Chatham responded to an invitation to have a clinical examination, lung function tests and a full size PA chest radiograph. From those aged 45 years and over a random sample of 135 was drawn. The number had to be limited by the time and resources available to seek and examine controls.

The controls were selected using data files compiled during earlier research by myself and by my predecessor at MRU, Dr P G Harries. These controls were matched one-to-one for sex, smoking habit, age to within one year and the potential for exposure to asbestos dust associated with their occupational group as defined in McMillan et al (1978). None was or had been a welder but all were skilled craftsmen employed in the Yards and were therefore considered to be of the same social class as the welders.

2.2 Examinations

The interview and clinical examinations were structured on the questionnaire used in the first part of the study (at Section C). Forced expiratory volume in one second (FEV_1) and Forced vital capacity (FVC) were measured with a McDermott dry spirometer. Transfer factor was measured by the single breath method using a Mk IV Morgan Resparameter. In subjects with FEV_1 greater than 2L the alveolar volumes measured simultaneously with transfer factor were used for the calculation of static lung volumes while in those with FEV_1 less than 2L the rebreathing Helium dilution method was used. The classification of men by smoking habit has been described in detail previously (McMillan et al, 1978).

2.3 Radiographic interpretation and analysis

Personal identification markings on the radiographs were obliterated by a label bearing a serial number allocated to each man. The list linking the number and identity was not available to the radiograph readers. The films were then mixed randomly with some 1200 similarly labelled films from other research studies and all were read idependently by three expert readers (Drs Elmes, Gilson and Sheers) to the ILO 1979 Classification of Radiographs of Pneumoconiosis. The analysis was limited to their scores for small regular opacities and for pleural fibrosis attributed to exposure to asbestos. The "agreed" reading of at least two of the three readers is used as the score of the film using the method described in McMillan and Rossiter (1982).

2.4 Analysis of lung function patterns

The simple method of classification described by Hunnicutt et al (1964) has been applied to determine if a man has a normal, obstructive, restrictive or mixed restrictive-obstructive pattern. Comparison of each index for welders and controls and their smoking habit sub-groups has utilised more refined statistical techniques devised, operated and interpreteted by Dr Pethybridge, Institute of Naval Medicine.

2.5 Statistical analysis

Four methods have been used in the various analysis of the data collected in the study. They are described in detail in books by Draper and Smith (1966) and Fleiss (1973).

(1) A test of the differences between two proportions p_1 and p_2, eg the incidence of symptoms in welders and controls, in which we evaluated the test statistic

$$Z = \frac{\text{Abs}\ (p_1 - p_2) \ - \ \frac{1}{2}\ \frac{1}{n_1} + \frac{1}{n_2}}{\sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}}$$

where abs( ) is the absolute value of ( ), p_1 and p_2 are the proportions "responding" in the two samples of size n_1 and n_2 and where $q_1 = 1 - p_1$, and $q_2 = 1 - p_2$.

(2) A comparison of three proportions, eg arising from the incidence of symptoms in the three smoking categories

$$\chi^2 = \frac{1}{\bar{p}\ \bar{q}} \sum_{i=1}^{3} n_i\ (p_i - \bar{p})^2$$

where p_i are the proportions "responding" in the three groups of size n_i, $\bar{p}$ is weighted average of the p_i and $\bar{q} = 1 - \bar{p}$.

(3) Cochrane's method of association employing the standardised difference

eg $d_i = \frac{p_{1i} - p_{2i}}{\bar{p}_i \quad \bar{q}_i}$ where $i = i^{th}$ smoking group, p_{1i} and p_{2i} are the proportions with eg respiratory symptoms in welders and controls and $\bar{p}_i$ = the weighted average of p_{1i} and p_{2i}, $\bar{q}_i = 1 - \bar{p}_i$. The method involves calculating χ^2 statistics which will provide answers to the following questions:-

a. Is there any association somewhere within the smoking groups? (χ^2 total). The measure of association is taken to be the standardised difference. The question being answered is "did similar proportions of welders and controls have for example respiratory symptoms in any of the smoking groups"?

b. Is there evidence that the degree of association, whatever its magnitude, is consistent from one smoking group to another? (χ^2 homog).

c. Assuming that the degree of association is found to be consistent, is the common degree of association statistically significant? (χ^2 assoc).

(4) Linear regression analysis of lung function, age and height. The linear relationship of lung function indices to age and height may be expressed in mathematical terms by the equation:-

Lung function index = $B_o + B_1$ age + B_2 height and error term (Equation 1)

which can also be written in the form:

$y = \bar{y} + B_1 (x - \bar{x}) + B_2 (z - \bar{z})$ + error term (Equation 2)

where y = lung function index, x = age, z = height and $\bar{x}, \bar{y}$, and $\bar{z}$ are the means of x, y and z respectively.

These equations are equivalent with $B_o = \bar{y} - B_1\bar{x} - B_2\bar{z}$. For a given data set the parameters B_1 and B_2 are estimated by least squares analysis.

The relationships of lung function measurements (FEV_1, FVC, RV, TLC and TF) to age (years) and height (metres) have been determined independently for the welders and their age matched controls. In table D12 the averages of the lung function measurements ($\bar{y}$), age ($\bar{x}$) and height ($\bar{z}$) and parameter estimate (with standard errors B_1 and B_2) are shown. In some publications the constant term B_o is given but this can be calculated easily from the information given in the tables if there is a wish to make limited comparisons with future studies. The standard deviation about the regression relationship is denoted by $\hat{\sigma}$. R^2 is the proportion of the total variation accounted for by the regression equation. Standard errors to the estimated parameters provide some measure of their reliability. For some of the lung function measures examined the parameter estimates are at most (in absolute terms) of the same magnitude as the standard errors and this might suggest that the age and/or height terms in the regression equated could be deleted.

Three dimensions are required to show the regression planes, ie the relationship of lung function to age and height. Two dimensional impressions of the various lung function relationships were created in diagram form with age plotted on the x axis and height set to 1.70 metres which is close to the average height of the men. Relationships for other heights for a given group or subgroup are parallel to those shown in these figures and can be calculated from equation 2 using the estimated parameters given in table D12. When B_2 is positive the relationships for heights over 1.70 metres will be above that displayed and below for lesser heights. The reverse holds for negative B_2.

The data sets were subjected to further analyses to determine if relationships for welders and controls were similar and, if not in which way they differed. Four different situations have been studied using various mathematical models.

Model 1.

Common relationship for welders and controls with age and height parameters ignored, ie no difference exists between the lung function indices of the welders and controls.

Lung function index = B_o + error term.

Model 2.

Common relationship for welders and controls with age and height parameters included, ie no difference exists between the lung function index for welders and controls after adjusting for age and height.

Lung function index = $B_o + B_1$age + B_2 heigh + error term.

Model 3.

Relationships for welders and controls are different but differ only by a constant as the regression planes are parallel.

$$\text{Lung function index (welder)} = B_{o,w} + B_1 \text{ age} + B_2 \text{ height} + \text{error term}$$

$$\text{Lung function index (control)} = B_{o,c} + B_1 \text{ age} + B_2 \text{ height} + \text{error term.}$$

Model 4.

Relationships for welders and controls are different with the regression planes not parallel. In this model the parameters B_1 and/or B_2 are different for welders and controls.

$$\text{Lung function index (welder)} = B_{o,w} + B_1 \text{ age} + B_2 \text{ height} + \text{error term}$$

$$\text{Lung function index (control)} = B_{o,c} + B_1 \text{ age} + B_2 \text{ height} + \text{error term.}$$

A sub-model of model 4 could be considered where the parameter B_2 (associated with height) is the same for welders and controls but the parameter B_1 is different. This is less restrictive than model 2.

The comparison of models follows the standard procedure explained in text books on regression analysis such as Draper and Smith (1966). Analysis of variance tables for each of the lung function indices were prepared for all data and separately for the three smoking habit sub-groups. Comments on the regression analysis have been restricted to that carried out on the whole groups of welders and controls as the relatively small number of men in some of the sub-groups make the defined relationships suspect. This does not detract significantly from the analysis as the men were carefully matched for smoking habit.

Unless otherwise stated the 5% significance level applies when significant results are quoted.

3. RESULTS

3.1 Age

The age frequency distributions of the welders and controls (table D1) reveal apparent discrepancies in age matching but these are in fact due solely to a slight "excess" of welders aged 54 years and of controls aged 55 years. These differences are unlikely to have any biological significance in the interpretation of the results especially as the actual age of the subjects were used in all statistical calculations.

3.2 Smoking habits

There were 68 smokers, 44 ex-smokers and 23 non-smokers in each group (table D1). All were age matched.

3.3 Duration of employment as a welder

On average the welders had been in that occupation for 33.1 years with very little difference in welders in the three smoking sub-groups (table D2). Nine had been welders for less than 25 years and two had been in the craft for at least 45 years. All the men had been employed on manual metal arc welding usually of mild steel using rutile or low hydrogen rods but two had done more metal inert gas welding and four men more tungsten inert gas welding than manual.

3.4 Past history of respiratory diseases during working life

There were no significant differences in the proportion of welders and controls who reported having had respiratory disease (pleurisy, tuberculosis, bronchitis and/or pneumonia) during the time they had been employed (table D3). Chest disease and in particular bronchitis was reported least often by non-smokers in both groups.

3.5 Respiratory and cardiovascular symptoms

There were no significant differences between welders and controls with regard to the proportion who suffered chronic cough, chronic phlegm, chronic cough and phlegm, angina or who had had haemoptysis (table D4). All these symptoms were least common in the non-smokers.

Dyspnoea was more common (significant at the 5% level) in welders (38 men, 28.1%) than in controls (10 men, 7.4%) (table D4). No welder had greater than grade 3 dyspnoea while one control had grade 4 and another grade 5. The association (significant at the 5% level) between smoking habit and dyspnoea is consistent in welders and controls, with dyspnoea more common in smokers than ex-smokers. Five non-smoker welders had dyspnoea (grade 2) while no non-smoker control reported that symptom. (Grades shown on questionnaire).

3.6 Clinical examination of the chest

A similar proportion of welders and controls had rhonchi. A higher proportion of controls than welders had persistent basal crackles (rales) (table D5) but the difference was not statistically significant. The association (significant at the 5% level) between the presence of basal crackles and smoking habit is not consistent in welders and controls as welder ex-smokers and control smokers have the highest prevalence in their respective groups.

3.7 Chest radiography

Although reader 3 recorded a higher proportion of small regular opacities category 1/1 or more (considered to be the minimum criteria of definite abnormality) there were no significant differences between the readers' scores (table D6: Chi-square = 3.31 for 2 degrees of freedom, method b.). Using the agreed scores of two or more readers, four welders and one control had small regular opacities in profusion 1/1 or more and six welders and three controls were in the 1/0 category (table D7). There were no abnormalities in excess of profusion category 1/1. All those with abnormalities were smokers or ex-smokers. There was virtually complete agreement between readers regarding the presence or absence of pleural fibrosis of which there was a significantly higher prevalence in welders and a significant positive association between the presence of pleural plaques and smoking habit in both groups with a stronger association in the welders (table D7).

3.8 Presence of respiratory abnormality as diagnosed by spirometry

Comparing the proportion of welders and controls with "normal" spirometry with those with "abnormal" results there is no significant difference (table D8). Overall there is a significant positive association between "abnormal" results and smoking habit, significantly stronger in the controls. In making separate comparisons of the prevalence of restrictive and obstructive patterns those men who demonstrated mixed patterns are included in both restrictive and obstructive. The prevalence of obstructive lung function patterns was not significantly different in welders and controls (ignoring smoking habit) but there was a significant positive association with smoking habit and again this was stronger in the controls. The difference in the prevalence of restrictive pattern of lung function is significant at the 6% level with welders having the higher prevalence. The association with smoking habit is similarly significant at 6% level; ex-smokers have the highest prevalence in the welders and non-smokers in the controls. Of the 38 welders who reported dyspnoea, 18 had normal spirometry, nine showed an obstructive pattern, five a restrictive and six a mixed pattern, (table D9).

3.9 Comparison of lung function measurements of welders and controls

As some of the estimated relationships between lung function and age and height are based on small numbers, particularly in the non-smokers sub-group, these cannot be considered to be indicative of relationships to be expected for either similar size or larger groups of welders and controls and therefore, although the results of analysis of data of these sub-groups are included in tables D11-16, comments are restricted to those relating to the entire 135 welders and their controls within the age range 45-65 years.

In deciding on an appropriate model to describe lung function relationships of welders and controls simultaneously, various smoking sub-groups are combined and the model parameters estimated. A summary of the appropriate models and the estimated parameters are given in table D11. Table D12 provides a summary of parameter estimates for various smoking categories of welders and controls; the welders and controls and their smoking sub-groups have been treated independently in the estimation process. (Much of the detailed information in these tables is for the use of future workers in welders lung function.) The independently estimated relationships between lung function and height and age for welders and controls are represented in figures D1 to D5.

Welders FEV_1 appears to reduce at a rate of 60 ml/year (table D11) compared to 40 ml in controls. However, the apparent differences in rate of decrease of FEV_1 with age between all welders and all controls are not statistically significant. The relationship between FEV_1 of welders and controls (ignoring smoking habit) can be described by model 3 (separate parallel planes with common age and height co-efficients) despite the suggestion of different co-efficients of age and height for the two groups when the relationships are estimated independently (tables D12 and figure D1).

The estimated difference (as calculated from model 3) between the FEV_1 of an "average" welder and control of the same height and age (ignoring smoking habit) is 215mls. Ex-smokers show the greatest differences between the welders and controls for FEV_1. Model 3 also best describes these relationships for FVC and FEV_1/FVC. The B_1 and B_2 parameters are much more obviously similar for these lung function indices (table D12 and figure D2).

Residual volume increases year by year more in welders than in controls and welders' total lung capacity reduces more slowly than the ageing process in controls (table D12). The relationship between RV, TLC and RV/TLC for welders and controls is best described by model 4, regression planes not parallel, the welders having generally higher values than controls and the differences increasing with age (figures D4 - 6). The estimated difference in RV values between a welder and control at average height (1.70m) and age (55 yrs) (for this group of men) is 255mls, the welder having the higher RV value. The change in RV with age is estimated at 33 mls per year for welders and 1ml per year for controls. The rates of increase are significantly differen The estimated differences in TLC between a welder and control at average height and age for this group is 132mls with the welder having the higher value. The average decrease in the TLC with age for welders is 13mls per year and 45 mls for controls. The estimated differences in RV/TLC% for a welder and control of average height and age for this group is 3.3% welders having the higher value with an average increase of 0.59% per year for welders and 0.26% for controls.

There are no significant differences in average values (adjusted for age and height) and the changes with age and height between welders and controls with respect to gas transfer factor, the relationship being described by model 2. Figure D7 shows the independently estimated TF relationship with height (=1.70m) and age for welders and controls.

4. DISCUSSION

4.1 Methods

If welding causes or contributes to respiratory disease there should be statistically and biologically significnat differences in the prevalence of symptoms, signs and radiographic and/or lung function abnormalities in welders over controls. As tobacco smoking is known to be causally related with respiratory diseases these differences should persist in all smoking categories unless there is an essential additive or synergistic effect of welding fumes or gases and tobacco smoke in which case the differences would be absent or less apparent in the non-smoking sub-groups.

Several investigators have sought to demonstrate a causal relationship between welding and disorders of the respiratory system. The variation in their findings and conclusions has resulted in confusion and debate fired by lay advocates of opposing factions electing to quote only the findings which suit their purposes and not mentioning the difficulties of forming a reasoned conclusion. It is vital to accept that several variables may act simultaneously upon the respiratory health of welders and these are not all occupational. This makes extrapolation of findings from one group of welders in one exposure environment to another group with perhaps different exposure fraught with hazard unless great care has been taken to ensure that the experimental design and interpretation of findings are valid and that the important variables are truly common to each group. The nature and concentration of the fumes and gases to which the welders are exposed and the duration of their exposure are thought to be crucial variables. For example, the very high concentrations experienced by the welders described by Slepika and his colleagues (1974) does not equate with the experience of the Dockyard welders in this study and therefore it would be imprudent to translate the conclusions drawn by that group of workers to the Dockyard welders. Exposure to harmful dusts which are not related to the welding process may be the true cause of respiratory diseases noted in welders;

asbestos is probably the most common significant dust in this context. Regrettably few published papers contain any information on the type or concentration of exposure and some complicate the issue still further by drawing welders from several different industries to form a group of statistically acceptable size. The working conditions and probable exposure of the welders in this study have been described (Evans et al, 1979., McMillan and Molyneux, 1981., Holden et al, 1978) and their exposure to asbestos has been mentioned in a study of Dockyard workers (McMillan et al, 1978) and is described in detail in an associated report in this series.

As mentioned above tobacco smoking is known to be causally related to several respiratory disorders and to reduction in some aspects of pulmonary function (Bosse et al, 1980). There are difficulties in comparing the experience of the various smoking habit sub-groups reported on in the literature because of variation in definition of these sub-groups. Ex-smokers appear to present the greatest difficulty. They have been grouped with non-smokers (Fogh et al, 1969., Ahbarkhanzadeah, 1980) and with current smokers (Hunnicutt et al, 1964). Earlier studies give no cognisance of the importance of tobacco smoking.

Problems also arise with variation in the definition of terms used particularly chronic bronchitis though in recent years the MRC definition is being used increasingly.

Some papers contain an element of mystery as welders "disappear" from the study apparently without reason and one is left wondering if the remainder are a representative sample of the groups mentioned originally while in others welders and controls with "significant" (but undefined) respiratory or cardiovascular conditions have been excluded.

Selection of inappropriate controls can make the findings rather suspect for example when white collar clerks are chosen as the controls for blue collar welders. Controls who are said to be matched for defined factors may turn out to be so matched by good fortune rather than design or not truly matched at all. In the present study great care was taken to match the welders and controls for the important variables but the results of the prevalence of pleural plaques suggests that even these efforts failed to achieve accurate matching for actual rather than potential exposure to asbestos at work.

These often insurmountable barriers to comparing the results of this study with those by earlier workers have been fully recognised and the results of other researchers are presented only for interest.

The conclusions of any research study may be affected by the choice of statistical methods and interpretation of the results of the statistical calculations. These results are especially susceptible to misrepresenting the truth when relatively small numbers of cases and controls are involved. Thus, while I am confident that the statistical methods used are entirely appropriate whenever a small data set yielded large numerical differences (although non-significant in a statistical sense) between welders and controls no firm conclusions have been based on it.

It is believed that the "limited" conclusions from this study are based on sound evidence drawn from a larger group of older welders with longer experience than has been described before and who should reveal any evidence of respiratory disorders detectable by the methods used and which are causally linked with welding in the Dockyards.

4.2 Results

The similarity of incidence of respiratory disorders occurring during working life reported by welders and controls bears out the findings of the study of absence attributed to sickness conducted as an associated part of this research project (McMillan and Molyneux, 1981., McMillan, 1981).

The observed similarities in the prevalence of cough and/or phlegm between the welders and controls are similar to the findings of Fogh et al (1969), Kleinfeld et al, (1969), and Peters et al (1973) but run contrary to the findings of others who found welders to be affected more than controls especially if they smoked (Hunnicutt et al, 1964., Donoso et al, 1974., Slepika et al, 1974., Barhad et al, 1975., Antti-Poika et al, 1977., and Ahbarkhanzadeh, 1980).

In contrast, dyspnoea was significantly more common in welders especially among the smokers. Similar findings have been reported by Hunnicutt et al (1964) and Barhad et al (1975), the latter noting that the differences were less striking in the smokers. However, in the present study there is a definite difference in the experience of the small number of non-smokers in the two groups with four welders who have never smoked reporting dyspnoea while none of the controls in that category reported that symptom.

It could be argued that these differences supports a causal relationship between welding and a respiratory disorder which causes dyspnoea but that argument holds only if one type of disorder was responsible for the excess. This view is only minimally supported by the very slight excess of restrictive type lung function abnormality pattern in welders with dyspnoea especially as no common relationship with smoking habits was found in this study. In their lung function study of welders Meo and his colleagues (1966) found that obstructive pattern disorders were most common. The argument is weakened further by the very small number of welders with positive clinical signs. Kleinfeld et al (1969) found no strong relationships between clinical signs, x-ray appearances, lung function and duration of exposure.

Only four welders had radiographic evidence consistent with the diagnosis of siderosis. Direct comparison of that prevalence with the findings of others is prevented by the absence of use of one common definition but their findings are listed at table A for interest. However, the relatively low prevalence of siderosis suggests that exposure to fumes may have been much lower than in many of the other groups of welders studied.

TABLE A. Prevalence of siderosis in published studies of welders' health

Authors	Number of welders	Percentage with siderosis
Britton and Walsh, 1940	256	10
Grohr, 1944	80	7
Sander, 1944	500	7
Ahlmark and Lonnberg, 1953	110	0
Haglind, 1957	450	10
Schuler et al, 1962	210	17
Hunnicutt et al, 1964	100	34
Lucionni et al, 1966	163	18
Stanescu et al, 1967	52	31
Fogh et al, 1969	156	8
Kleinfeld et al, 1969	25	32
Peters et al, 1973	61	0
Donoso et al, 1974	57	28
Barhad et al, 1975	50	36
Pikulskaya and Gulko, 1975	473	13
Spacilova and Koval, 1975	37	80
Attfield and Ross, 1978	66	7

These four men had been employed mainly on manual metal arc welding for periods between 32 and 44 years. One had been exposed to heavy concentrations of asbestos dust during limpet asbestos spraying. Three men had chronic morning productive cough but spirometry was normal in two, the other having a mild degree of obstruction. The fourth man had a restrictive ventilatory defect on spirometry but his transfer factor was normal. There were no abnormal clinical signs in any of the cases. This mixture of symptoms and lung function results does not support a hypothesis of a causal relationship between welding and a specific respiratory disorder.

The higher prevalence of pleural changes attributable to asbestos exposure suggest that, despite all efforts to match cases and controls for potential exposure to that dust at work the welders did actually have more exposure. This may be the reason for the weakly significant excess of restrictive type lung function pattern (table D8). However, overall the absence of differences in lung function pattern abnormalities weighs against welding causing respiratory disease in these welders. Ahlmark and Lonneberg (1953), Haglind (1957)., Pilat et al (1963)., Kleinfeld et al (1969)., Peters et al (1973 and Antti-Poika et al (1977) found no significant differences between lung function of controls and welders in their studies.

In this study it has been found that after adjustment for age and height FEV_1 and RV appear to increase more with age and TLC decreases less with age in welders than controls although only the differences in rate of change with age in RV are statistically significant. Thus there is a slight suspicion of welding being causally related to obstructive airways disease with emphysema. The absence of differences in transfer factor support the view that there is no parenchymal fibrosis attributable to welding.

5. CONCLUSIONS

It is considered that this study has produced no convincing evidence to support the hypothesis that prolonged exposure to fumes and gases arising from the welding processes used in the Dockyards is causally related to respiratory disease. There is a slight suspicion that there may well be an excess of obstructive airways disease in the welders. The size of the study groups is not large enough to confirm or deny that suspicion statistically using the investigative procedures available. It is estimated that some 300 welders over 45 years of age would be required to achieve this, a number in excess of the total in all HM Dockyards. The evidence does justify the conclusion that welding does not cause significant parenchymal fibrosis as transfer factor is not reduced and total lung capacity reduces less with time in welders than controls.

It is thought that the low incidence and degree of radiographic evidence of siderosis reflects the relatively low exposure of Dockyard welders compared to other studied groups even although they frequently worked in confined and poorly ventilated areas.

In summary; there is a suspicion that welding may be related to obstructive airways disease but in this large and long exposed group it has not produced any dramatic overt ill-health. A final answer would require a long term prospective study. This is impossible on two counts. First the announced closure/reduction of two of the three Dockyards will prevent access to these men and is likely to stop many of them ever being exposed to similar work situations again. Second, the interest in welders' health generated by this study appears to have resulted in greater attention being paid to reducing emission of fume and removing the rest at source. This can only be good for the welders.

REFERENCES

AHLMARK, A., and LONNEBERG, B. (1953).

A clinical examination of workers with more than 5 years continuous welding experience.

Nord. Hyg. Tidskr. 34,238.

A BARKHANZADEH, F. (1980).

Long term effects of welding fumes upon respiratory symptoms and pulmonary function.

J. Occ. Med. 22,5,37.

ANTTI-POIKA, M., HASSI, J., and PYY, L. (1977).

Respiratory diseases in arc welders.

Int. Arch. Occup. Environ. Hlth. 40,3,225.

ATTFIELD, M.D. and ROSS, D.S. (1978).

Radiological abnormalities in electric arc welders.

Br. J. Ind. Med. 35,117.

BARHAD, B., TECULESCU, D., and CRACUIN, D. (1955).

Respiratory symptoms, chronic bronchitis and ventilatory function in shipyard welders.

Int. Arch. Occup. Enviorn. Hlth. 36,137.

BOSSE, R., SPARROW, D., GARVEY, A.J., COSTA, P.T., WEST, S.T. and ROWE. (1980).

Cigarette smoking, aging and decline in pulmonary function:

Arch. Enviorn. Hlth. 35,4,247.

BRITTON, J.F., and WALSH, E.L. (1940).

Health hazards of electric welding.

J. Ind. Hyg. Toxicol 22,125.

DONOSO, H., SEGURA, E., VALLEJOS, M.E., and LORONS. (1974)
Arc welders' siderosis.
Rev. Med. Chil. 102,3,202.

EVANS, M.J., INGLE, J., MOLYNEUX, M.K., SHARP, G.T.H. and SWAIN, J. (1979).
An occupational hygiene study of a controlled welding task using a general purpose rutile electrode.
Ann. Occup. Hyg. Vol 22,1.

FLEISS, J.L. (1973).
Statistical methods for rates and proportions.
J. Wiley and Sons.

FOGH, A., FROST, J., and GEORG, J. (1969).
Respiratory symptoms and pulmonary function in welders.
Arch. Environ. Hlth. 8,661.

GROHR, J.A. (1944).
Benign pulmonary changes in arc welders.
Ind. Med. 13,8,598.

HAGLIND, O. (1957).
Lung changes in electric welders.
Proceedings of the XII International Congress on Occupational Health III: 169-171.

HOLDEN, H.J., INGLE, J., MOLYNEUX, M.K.B., and GISBORNE, J.T. (1978).
Occupational hygiene study of Dockyard welding processes: a work situation survey report.
Institute of Naval Medicine Report No. 45/78.

HUNNICUTT, T.N., CRACOVANER, D.J., and MYLES, J.T. (1964).
Spirometric measurements in welders.
Arch. Environ. Health, 8,661.

KLEINFELD, M., MESSITE, J., KOOYMAN, O., and SHAPIRO, J. (1969).
Welders' siderosis; a clinical, roentgenographic and physiological study.
Arch. Environ. Health. 19,70.

LUCCIONI, R., CHARPIN, J., and MOSINGER, M. (1966).
Pulmonary siderosis in arc welders.
Arch. Mal. Prof. 27,803.

MEO, G., SULLOTTO, F., and LACOVANITI, A. (1966).
Damage to respiratory function in welders with lung siderosis.
Folia. Med. (Napoli) 49,506.

McMILLAN, G.H.G., SHEERS, G., and PETHYBRIDGE, R. (1978).
A radiological follow-up study of the effect of asbestos in Dockyard workers at Devonport.
J. Roy. Nav. Med. Ser. 64,88.

McMILLAN, G.H.G., and HEATH, J. (1979).
The health of welders in Naval Dockyards: Acute changes in respiratory function during standardized welding.
Ann. Occup. Hy. 22,19.

McMILLAN, G.H.G., and MOLYNEUX, M.K. (1981).
The health of welders in Naval Dockyards: the work situation and sickness absence patterns.
J. Soc. Occup. Med. 31,43.

McMILLAN, G.H.G. (1981).
The health of welders in Naval Dockyards: Welding, tobacco smoking and absence attributed to respiratory diseases.
J. Soc. Occup. Med. 31.112.

McMILLAN, G.H.G., and ROSSITER, C.E. (1982).
Development of radiological and clinical evidence of parenchymal fibrosis in men with non-malignant asbestos related pleural lesions.
Br. J. Ind. Med. 39,54.

OXHOJ, H., BAKE, B., WEDEL, H., and WILHEMSEN, L. (1979).
Effects of electric arc welding on ventilatory lung function.
Arch. Environ. Hlth. July/August, 211.

PETERS, J.M., MURPHY, R.L.H., FERRIS, B.G., BURGESS, W.A., RANADINE, M.V., and PENDERGRASS, H.P. (1973).
Pulmonary function in shipyard welders.
Arch. Environ. Health 26,1,28.

PIKULSKAYA, A.F., and GULKO, S.N. (1975).
External respiration and drainage function of the bronchii in electric welders.
Vrach Delo. 1,127. Read in English abstract only.

PILAT, L., LILIS, R., and CRACIVIA, O. (1963).
Med. Interne (Buc) 15,213.
cited by Stanescu, 1967.

SANDER, O.A. (1944).
Further observations on lung changes in electric welders.
J. Ind. Hyg. 26,80.

SCHULER, P., MATURANA, V., CRUZ, E., GUIJON, C., VASQUEZ, A., VALENZUELA, A., and SILVA, R. (1962).
Arc welders' pulmonary siderosis.
J. Occup. Med. 4,353.

SLEPICKA, J., TESAR, Z., and MIREJOVSKY, P. (1974).
The effect of electric arc welding upon the respiratory tract of welders.
Pracov Lek 26. 295-302.
read in English translation.

SPACILOVA, M., and KOVAL, Z. (1975).
Pulmonary x-ray and function findings in electric arc welders.
Int. Arch. Arbeitsmed 34,3,231.

STANESCU, D.C., PILAT, L., GAVRILESCU, N., TECULESCU, P.B., and CRISTESCU, I. (1967
Aspects of Pulmonary Mechanics in arc welders' siderosis.
Br. J. Ind. Med. 24,143.

TABLE D1. Age frequency distribution, mean age and smoking habits of welders and controls

Smoking habit	Welders' age (years)				Controls' age (years)			
	45-54	55-64	All	Mean age	45-54	55-64	All	Mean age
Smoker	33	35	68	54.9	30	38	68	55.9
Ex-smoker	16	28	44	55.5	14	30	44	56.0
Non-smoker	11	12	23	54.8	10	13	23	55.1
All	60	75	135	55.1	54	81	135	55.8

TABLE D2. Duration of employment as a welder

Smoking habit	Time (years)								Mean (Years)
	15-19	20-24	25-29	30-34	35-39	40-44	45-49	All	
Smoker	2	2	17	12	21	13	1	68	33.2
Ex-smoker	1	3	13	7	6	13	1	44	32.8
Non-smoker	0	1	6	6	8	2	0	23	32.8
All	3	6	36	25	35	28	2	135	33.1

TABLE D3. Number (and %)of welders and controls who gave a history of chest disease during their working lives.

Smoking habit	Welders			
	Pleurisy	Tuberculosis	Bronchitis	Pneumonia
Smoker	8 (11.8)	2 (2.9)	19 (27.9)	10 (14.7)
Ex-smoker	8 (18.2)	0 (0.0)	20 (45.4)	4 (9.1)
Non-smoker	1 (4.3)	0 (0.0)	3 (12.9)	2 (8.6)
All	17 (12.6)	2 (1.5)	42 (31.1)	16 (11.8)
Smoking habit	**Controls**			
	Pleurisy	Tuberculosis	Bronchitis	Pneumonia
Smoker	4 (5.9)	1 (1.5)	12 (17.6)	8 (11.8)
Ex-smoker	9 (20.4)	1 (2.3)	24 (54.5)	7 (15.9)
Non-smoker	1 (4.3)	0 (0.0)	1 (4.3)	2 (8.6)
All	14 (10.4)	2 (1.5)	37 (27.4)	17 (12.6)

TABLE D4. Respiratory and cardiovascular symptoms reported by welders and controls

Symptoms	Welders				Controls			
	Smoker	Ex-Smoker	Non-Smoker	All	Smoker	Ex-Smoker	Non-Smoker	All
Chronic* cough	20	7	1	28	12	6	2	20
Chronic* morning phlegm	22	5	1	28	16	5	4	25
Chronic* cough and phlegm	13	4	0	17	9	4	2	15
Dyspnoea Grade 2	14	9	5	28	6	0	0	6
3	7	3	0	10	1	0	0	1
4	0	0	0	0	0	1	0	1
5	0	0	0	0	1	1	0	2
Dyspnoea all grades	21	12	5	38	8	2	0	10
Haemoptysis in past	7	5	2	14	5	3	1	9
Angina of effort	2	2	0	4	3	1	0	4

*Most mornings for at least 3 consecutive months of the year for 2 years or more.

TABLE D5. Clinical signs observed on examination of the chest

Sign	Welders				Controls			
	Smoker	Ex-Smoker	Non-Smoker	All	Smoker	Ex-Smoker	Non-Smoker	All
Rhonchi	7	3	2	12	6	2	2	10
Persistent rales	2	6	0	8	12	2	1	15

TABLE D6. Comparison of radiograph readers' score for small opacities RR,RI 1/1 or more

X-Ray abnormality		Reader		
		1	2	3
Small opacities RR,RI 1/1 or more	Present	10	9	17
	Absent	260	261	253

TABLE D7 Agreed* radiographic classification for presence of small opacities and presence of pleural fibrosis (PF)

Smoking Habit	Welders					Controls				
	0/0	0/1	1/0	1/1	PF	0/0	0/1	1/0	1/1	PF
Smoker	52	9	3	4	24	59	5	3	1	7
Ex-smoker	39	2	3	0	8	44	0	0	0	9
Non-smoker	23	0	0	0	3	23	0	0	0	3
All	114	11	6	4	35	126	5	3	1	19

*Agreed score of 2 or more readers.

TABLE D8. Prevalence of respiratory disease in welders and controls diagnosed by spirometry

Smoking habit	Number	Welders					Controls				
		Normal	Obst.	Rest.	Mixed*	Total Abnormal	Normal	Obst.	Rest.	Mixed*	Total Abnormal
Smoker	68	36	15	8	9	32	31	23	8	6	37
Ex-smoker	44	26	5	7	6	18	33	9	1	1	11
Non-smoker	23	12	6	3	2	11	17	0	5	1	6
All	135	74	26	18	17	61	81	32	14	8	54

*Mixed = obstructive and restrictive changes present

TABLE D9. Prevalence of respiratory disease in welders complaining of dyspnoea as diagnosed by spirometry

Smoking habit	Normal	Obstructive	Restrictive	Mixed
Smoker	8	7	2	4
Ex-smoker	8	0	2	2
Non-smoker	2	2	1	0
All	18	9	5	6

TABLE D10. Height (cms) distribution of welders and controls

Smoking habit	Welders					Controls				
	155-164	165-174	175-184	185-189	All	155-164	165-174	175-184	185-189	All
Smoker	8	40	19	1	68	8	47	12	1	68
Ex-smoker	8	26	8	2	44	3	31	9	1	44
Non-smoker	8	11	4	0	23	7	10	5	1	23
All	24	77	31	3	135	18	88	26	3	135

TABLE D11. Estimated parameters (and standard errors) of models describing the lung function relationship of welders and controls

Lung function parameter	Smoking habits	Number in each group	Model No.	Parameter estimates (and standard errors) $B_{o,w}$	$B_{o,c}$	B_1	B_2	$\hat{\sigma}$	R^2
FEV	All	135	3	400(1058)	614(1062)	-50.01(8.07)	3070(553)	606	0.23
	Smokers	68	2	-648(1635)		-43.34(10.47)	3480(877)	582	0.21
	Ex-smokers	44	3	905(1854)	1309(1873)	-55.18(14.41)	2938(1047)	585	0.28
	Non-smokers	23	2	859(2583)		-54.41(24.00)	3098(1122)	575	0.29
FVC	All	135	3	-1216(1052)	-1042(1056)	-47.61(8.03)	4612(550)	602	0.30
	Smokers	68	2	-2460(1580)		-47.81(10.11)	5363(848)	563	0.33
	Ex-smokers	44	3	-1164(1828)	-791(1847)	-44.23(14.21)	4457(1033)	577	0.31
	Non-smokers	23	2	995(2856)		-55.20(26.53)	3611(1240)	746	0.29
%FEV/FVC	All	135	3	93.5(16.8)	96.0(16.9)	-0.373(0.128)	-1.13(8.8)	9.6	0.04
	Smokers	68	4	143.8(38.3)	45.9(35.4)	{W -0.677(0.230) {C 0.206(0.249)	-20.9(19.7)} 7.6(20.2)}	9.2	0.7
	Ex-smokers	44	1	72.7(1.1)		0	0	9.8	0
	Non-smokers	23	3	88.6(35.2)	95.9(35.3)	-0.489(0.327)	6.32(15.28)	9.2	0.19
RV	All	135	4	-4633(1228)	896(1137)	{W 33.37(8.76) {C 1.19(9.32)	3001(630)} 655(607)}	477	0.16
	Smokers	68	4	-6100(1877)	-448(1735)	{W 51.81(11.27) {C 5.05(12.17)	3289(963)} 1345(993)}	451	0.24
	Ex-smokers	44	3	-249 (1797)	-574(1815)	-1.86(13.96)	1604(1015)	567	0.09
	Non-smokers	23	4	-3206(1831)	2240(1454)	{W 13.67(13.33) {C -5.44(15.62)	2657(884)} -10(562)}	284	0.20
TLC	All	135	4	-5604(1893)	-142(1752)	{W -12.69(13.50) {C -45.48(14.36)	7454(971)} 5237(936)}	735	0.28
	Smokers	68	4	-9453(2858)	-3236(2641)	{W 16.22(17.16) {C -52.91(18.52)	8776(1469)} 7278(1512)}	687	0.35
	Ex-smokers	44	2	-348(2436)		-47.66(19.06)	5570(1372)	774	0.19
	Non-smokers	23	2	1027(2942)		-48.52(27.34)	4582(1278)	769	0.33
%RV/TLC	All	135	4	-2.9(14.4)	50.3(13.3)	{W 0.593(0.103) {C 0.256(0.109)	3.8(7.4)} -18.4(7.1)}	5.7	0.17
	Smokers	68	3	30.9(15.8)	27.7(15.8)	0.522(0.101)	-13.3(8.5)	5.6	0.22
	Ex-smokers	44	3	30.9(18.4)	25.8(18.6)	0.237(0.143)	-4.1(10.4)	5.8	0.19
	Non-smokers	23	2	35.0(18.5)		0.344(0.172)	-12.6(8.0)	4.3	0.17
TF	All	135	2	30.2(30.8)		-0.801(0.235)	62.3(16.1)	17.5	0.09
	Smokers	68	2	-39.7(47.1)		-0.658(0.302)	95.1(25.3)	16.8	0.13
	Ex-smokers	44	2	31.3(56.4)		-0.951(0.441)	67.0(31.8)	17.9	0.09
	Non-smokers	23	2	88.7(53.1)		-1.187(0.493)	43.8(23.1)	13.9	0.23

NOTES: (1) In models 1 and 2 $B_{o,w} = B_{o,c}$. Also in model 1 B_1 and B_2 are both absent.

(2) For model 4 two sets of B_1's and B_2's are shown, a set for welders and a set for controls.

TABLE D12. Estimated parameters (and standard errors) of lung function, age and height relationships

Lung Function Parameter	Group*	No. in Group	Unadjusted average: LFT Value(cc)	Unadjusted average: Age (Years)	Unadjusted average: Height (Metres)	Parameter estimates and standard error: B_1 (age)	Parameter estimates and standard error: B_2 (height)	$\hat{\sigma}$	R^2
FEV_1	W (A)	135	2876	55.1	1.705	-59.76 (11.31)	2563 (849)	643	0.23
	C (A)	135	3065	55.8	1.707	-40.07 (11.05)	3437 (720)	566	0.21
	W (S)	68	2880	55.0	1.716	-55.92 (14.87)	2642 (1270)	595	0.26
	C (S)	68	2889	55.9	1.709	-34.60 (15.44)	4146 (1260)	572	0.18
	W (E)	44	2838	55.5	1.701	-62.60 (24.07)	2947 (1503)	690	0.19
	C (E)	44	3270	56.0	1.719	-47.78 (16.53)	2868 (1487)	471	0.20
	W (N)	23	2938	54.8	1.677	-67.24 (35.63)	2605 (2362)	759	0.25
	C (N)	23	3197	55.2	1.680	-41.05 (32.81)	3306 (1180)	596	0.39
FVC	W (A)	135	4021	55.1	1.705	-49.60 (11.61)	4469 (835)	632	0.29
	C (A)	135	4177	55.8	1.707	-45.69 (11.25)	4725 (733)	576	0.30
	W (S)	68	4056	55.0	1.716	-40.39 (14.27)	5331 (1219)	571	0.34
	C (S)	68	4096	55.9	1.709	-60.19 (14.98)	5827 (1222)	555	0.34
	W (E)	44	3960	55.5	1.701	-57.86 (21.98)	3780 (1372)	630	0.25
	C (E)	44	4393	56.0	1.719	-32.99 (18.19)	5775 (1636)	519	0.25
	W (N)	23	4036	54.8	1.677	-53.20 (39.69)	5207 (2631)	845	0.28
	C (N)	23	4002	55.2	1.680	-53.17 (37.45)	3009 (1347)	681	0.33
FEV_1/FVC%	W (A)	135	71.0	55.1	1.705	-0.634 (0.193)	-0.109 (0.138)	10.5	0.08
	C (A)	135	73.2	55.8	1.707	-0.098 (0.167)	0.051 (0.109)	8.5	0.004
	W (S)	68	70.7	55.0	1.716	-0.677 (0.232)	-0.209 (0.108)	9.3	0.12
	C (S)	68	70.3	55.9	1.709	0.206 (0.246)	-0.076 (0.201)	9.1	0.01
	W (E)	44	70.9	55.5	1.701	-0.502 (0.416)	0.120 (0.259)	11.9	0.04
	C (E)	44	74.5	56.0	1.719	-0.450 (0.235)	-0.144 (0.212)	5.7	0.11
	W (N)	23	72.4	54.8	1.677	-0.944 (0.557)	-0.347 (0.369)	11.9	0.13
	C (N)	23	79.5	55.2	1.680	0.044 (0.240)	0.250 (0.086)	4.4	0.31
RV	W (A)	135	2321	55.1	1.705	33.37 (9.31)	3001 (669)	507	0.18
	C (A)	135	2080	55.8	1.707	1.19 (8.69)	655 (566)	445	0.01
	W (S)	68	2392	55.0	1.716	51.81 (11.45)	3299 (978)	458	0.29
	C (S)	68	2132	55.9	1.709	5.05 (11.97)	1345 (977)	444	0.03
	W (E)	44	2381	55.5	1.701	6.79 (21.71)	2361 (1355)	622	0.07
	C (E)	44	2081	56.0	1.719	-7.37 (17.82)	84 (1603)	508	0.005
	W (N)	23	1999	54.8	1.677	13.67 (12.75)	2657 (844)	271	0.33
	C (N)	23	1923	55.2	1.680	-5.45 (16.28)	-1 (585)	296	0.005
TLC	W (A)	135	6403	55.1	1.705	-12.69 (12.79)	7454 (920)	696	0.34
	C (A)	135	6262	55.8	1.707	-45.48 (15.08)	5237 (982)	772	0.21
	W (S)	68	6502	55.0	1.716	16.22 (15.73)	8776 (1344)	630	0.40
	C (S)	68	6248	55.9	1.709	-52.91 (19.94)	7278 (1628)	739	0.27
	W (E)	44	6385	55.5	1.701	-49.36 (28.52)	5903 (1780)	818	0.24
	C (E)	44	6450	56.0	1.719	-44.58 (26.50)	4725 (2384)	755	0.12
	W (N)	23	6146	54.8	1.677	-31.85 (28.03)	8366 (1858)	597	0.57
	C (N)	23	5944	55.2	1.680	-59.08 (48.91)	3102 (1759)	889	0.24
RV/TLC%	W (A)	135	36.25	55.1	1.705	0.593 (0.116)	0.038 (0.083)	6.29	0.17
	C (A)	135	33.23	55.8	1.707	0.256 (0.094)	-0.184 (0.061)	4.81	0.11
	W (S)	68	36.79	55.0	1.716	0.649 (0.146)	-0.011 (0.124)	5.83	0.27
	C (S)	68	34.17	55.9	1.709	0.359 (0.143)	-0.212 (0.117)	5.31	0.12
	W (E)	44	37.13	55.5	1.701	0.382 (0.233)	0.029 (0.147)	6.74	0.06
	C (E)	44	32.09	56.0	1.719	0.117 (0.165)	-0.177 (0.149)	4.71	0.04
	W (N)	23	32.99	54.8	1.677	0.483 (0.302)	-0.009 (0.200)	6.42	0.12
	C (N)	23	32.62	55.2	1.680	0.185 (0.150)	-0.179 (0.054)	2.73	0.45
Transfer factor	W (A)	135	9.284	55.1	1.705	-0.994 (0.340)	0.524 (0.244)	18.49	0.10
	C (A)	135	9.136	55.8	1.707	-0.584 (0.329)	0.697 (0.214)	16.86	0.09
	W (S)	68	8.704	55.0	1.716	-0.597 (0.432)	0.678 (0.369)	17.29	0.09
	C (S)	68	8.644	55.9	1.709	-0.883 (0.433)	1.294 (0.361)	17.94	0.19
	W (E)	44	9.309	55.5	1.701	-1.547 (0.654)	0.757 (0.409)	18.78	0.17
	C (E)	44	9.764	56.0	1.719	-0.335 (0.505)	0.585 (0.545)	17.25	0.03
	W (N)	23	9.996	54.8	1.677	-1.438 (0.688)	0.398 (0.456)	14.64	0.37
	C (N)	23	9.391	55.2	1.680	-0.623 (0.682)	0.301 (0.245)	12.39	0.14

*Group W Welders, C Controls; (A) All, (S) Smokers; (E) Ex-smokers, (N) Non-smokers

Notes on analysis of variance table D13-16

1. The terms itemised under the 'source' (short for source of variation) column are to be understood as follows:-

'Total'	-	total variation about grand mean.
'Residual'	-	variation remaining after regression relationship of model 4 are fitted.
'Regression A'	-	difference in variations 'about regressions' as represented by models 3 and 4.
'Regression B'	-	difference in variations 'about regressions' as represented by models 2 and 3.
'Regression C'	-	difference in variation 'about regressions' as represented by models 1 and 2.

2. Mean square is the sum of squares divided by degrees of freedom.

3. F ratio is the mean square for 'regressions A, B or C' divided by the mean square for 'residual'.

4. Under appropriate statistical assumption on the residuals the significance of the F ratios can be assessed by reference to tables of the F distribution.

TABLE D13. Analysis of variance:- all welders and controls

Lung function parameter	Source	Degrees of freedom	Sum of squares	Mean Square	F ratio
FEV_1	Regression A	2	744000	372000	1.01
	" B	1	3078600	3078600	8.40
	" C	2	25597500	12798750	34.92
	Residual	264	96772900	366564	
	Total	269	126193000		
FVC	Regression A	2	39500	19750	0.05
	" B	1	2036700	2036700	5.57
	" C	2	39124300	19562150	53.52
	Residual	264	96497200	365520	
	Total	269	137697700		
$\frac{FEV_1}{FVC}$ %	Regression A	2	463.69	231.85	2.54
	" B	1	403.43	404.43	4.41
	" C	2	706.22	353.11	3.86
	Residual	264	24140.45	91.44	
	Total	269	25713.79		
RV	Regression A	2	2980300	1490150	6.55
	" B	1	4445400	4445400	19.55
	" C	2	4388300	2194150	9.65
	Residual	264	60044500	227441	
	Total	269	71858500		
TLC	Regression A	2	2864400	1432200	2.65
	" B	1	1290800	1290800	2.39
	" C	2	52333600	26166800	48.44
	Residual	264	142613900	540204	
	Total	269	199102700		
$\frac{RV}{TLC}$ %	Regression A	2	294.88	147.44	4.71
	" B	1	724.00	724.00	23.12
	" C	2	1006.46	503.23	16.07
	Residual	264	8267.19	31.32	
	Total	269	10292.53		
Transfer factor	Regression A	2	313.5	156.75	0.50
	" B	1	85.0	85.00	0.27
	" C	2	8560.7	4280.35	13.67
	Residual	264	82653.9	313.08	
	Total	269	91613.1		

TABLE D14. Analysis of variance:- smokers among welders and controls

Lung function parameter	Source	Degrees of freedom	Sum of squares	Mean Square	F ratio
FEV_1	Regression A	2	567100	283550	0.83
	" B	1	189500	189500	0.56
	" C	2	11801700	5900850	17.30
	Residual	130	44340600	341082	
	Total	135	56898900		
FVC	Regression A	2	319500	159750	0.50
	" " B	1	511500	511500	1.61
	" C	2	20618600	10309300	32.47
	Residual	130	41269100	317455	
	Total	135	62718700		
$\frac{FEV_1}{FVC}$ %	Regression A	2	654.94	327.47	3.86
	" B	1	0.43	0.43	0.01
	" C	2	181.47	90.74	1.07
	Residual	130	11038.25	84.91	
	Total	135	11875.09		
RV	Regression A	2	1991900	995950	4.89
	" B	1	2452200	2452200	12.48
	" C	2	3924900	1962450	9.64
	Residual	130	26459600	203535	
	Total	135	34828600		
TLC	Regression A	2	3743700	1871850	3.97
	" B	1	1126400	1126400	2.39
	" C	2	27451300	13725650	29.10
	Residual	130	61320200	471694	
	Total	135	93641600		
$\frac{RV}{TLC}$ %	Regression A	2	126.59	63.30	2.03
	" B	1	340.92	340.92	10.96
	" C	2	825.52	412.76	13.27
	Residual	130	4044.19	31.11	
	Total	135	5337.22		
Transfer factor	Regression A	2	470.4	235.2	0.83
	" B	1	16.3	16.3	0.06
	" C	2	5543.7	2771.9	9.75
	Residual	130	36949.6	284.2	
	Total	135	42980.0		

TABLE D15. Analysis of variance :- ex-smokers among welders and controls

Lung function parameters	Source	Degrees of freedom	Sum of squares	Mean Square	F ratio
FEV_1	Regression A	2	90400	45200	0.13
	" B	1	3507100	3507100	10.04
	" C	2	7419100	3709550	10.62
	Residual	82	28635900	349218	
	Total	87	39652500		
FVC	Regression A	2	620400	310200	0.93
	" B	1	2985700	2985700	8.96
	" C	2	9491900	4745950	14.25
	Residual	82	27311300	333065	
	Total	87	40409300		
$\frac{FEV_1}{FVC}$ %	Regression A	2	47.25	23.63	0.25
	" B	1	297.40	297.40	3.18
	" C	2	376.46	188.23	2.01
	Residual	82	7672.58	93.57	
	Total	87	8393.69		
RV	Regression A	2	507800	253900	0.79
	" B	1	2318400	2318400	7.18
	" C	2	468900	234450	0.73
	Residual	82	26473300	322845	
	Total	87	29768400		
TLC	Regression A	2	97000	48500	0.08
	" B	1	3700	3700	0.01
	" C	2	11943100	5971550	9.63
	Residual	82	50829100	619867	
	Total	87	62872900		
$\frac{RV}{TLC}$ %	Regression A	2	68.41	34.21	1.01
	" B	1	553.82	553.82	16.37
	" C	2	98.22	49.11	1.45
	Residual	82	2773.38	33.82	
	Total	87	3493.83		
Transfer factor	Regression A	2	601.7	300.85	0.93
	" B	1	36.5	36.50	0.11
	" C	2	2671.0	1335.50	4.11
	Residual	82	26667.2	325.21	
	Total	87	29976.4		

TABLE D16. Analysis of variance:- non-smokers among welders and controls

Lung function parameters	Source	Degrees of freedom	Sum of squares	Mean Square	F ratio
FEV_1	Regression A	2	139800	69900	0.15
	" B	1	829200	829200	1.78
	" C	2	8000800	4000400	8.60
	Residual	40	18615500	465388	
	Total	45	27585300		
FVC	Regression A	2	384600	192300	0.33
	" B	1	7900	7900	0.01
	" C	2	9732700	4866350	8.27
	Residual	40	23543400	588585	
	Total	45	33668600		
$\frac{FEV_1}{FVC}$ %	Regression A	2	353.12	176.56	2.21
	" B	1	599.55	599.55	7.51
	" C	2	227.88	113.94	1.43
	Residual	40	3194.86	79.87	
	Total	45	4375.41		
RV	Regression A	2	527050	263530	3.27
	" B	1	71240	71240	0.88
	" C	2	207740	103870	1.29
	Residual	40	3222620	80566	
	Total	45	4028650		
TLC	Regression A	2	2036500	1018250	1.78
	" B	1	453600	453600	0.79
	" C	2	12497000	6248500	10.91
	Residual	40	22919300	572983	
	Total	45	37906400		
$\frac{RV}{TLC}$ %	Regression A	2	29.97	14.99	0.62
	" B	1	2.44	2.44	0.10
	" C	2	207.34	103.67	4.24
	Residual	40	974.38	24.36	
	Total	45	1214.13		
Transfer factor	Regression A	2	530.5	265.25	1.44
	" B	1	383.0	383.00	2.08
	" C	2	2484.4	1242.20	6.75
	Residual	40	7356.9	183.92	
	Total	45	10754.8		

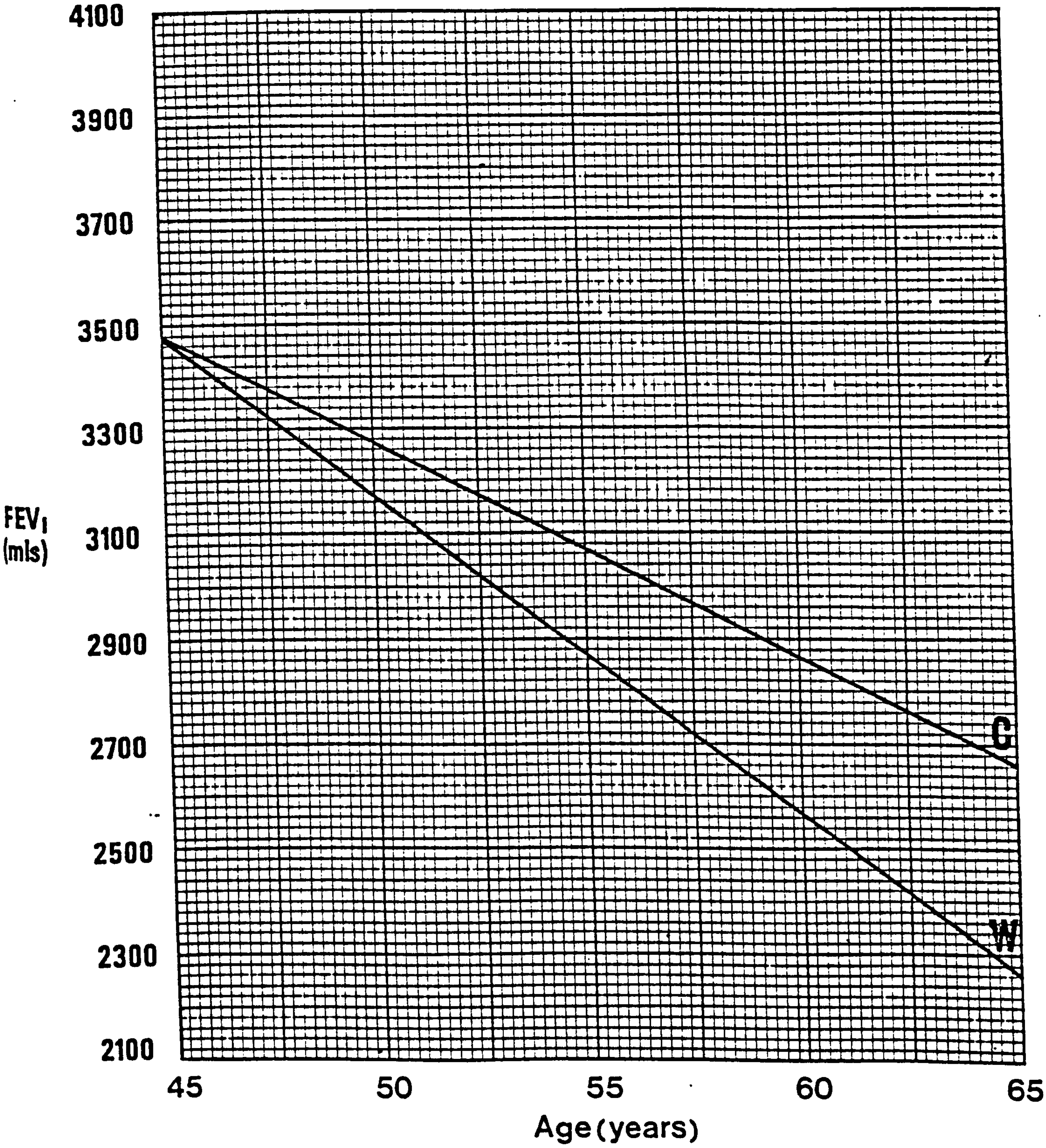


Figure D1 Two dimensional representation of relationship between FEV$_1$ and age for welders and controls of height 1.70m (ignoring smoking habit)

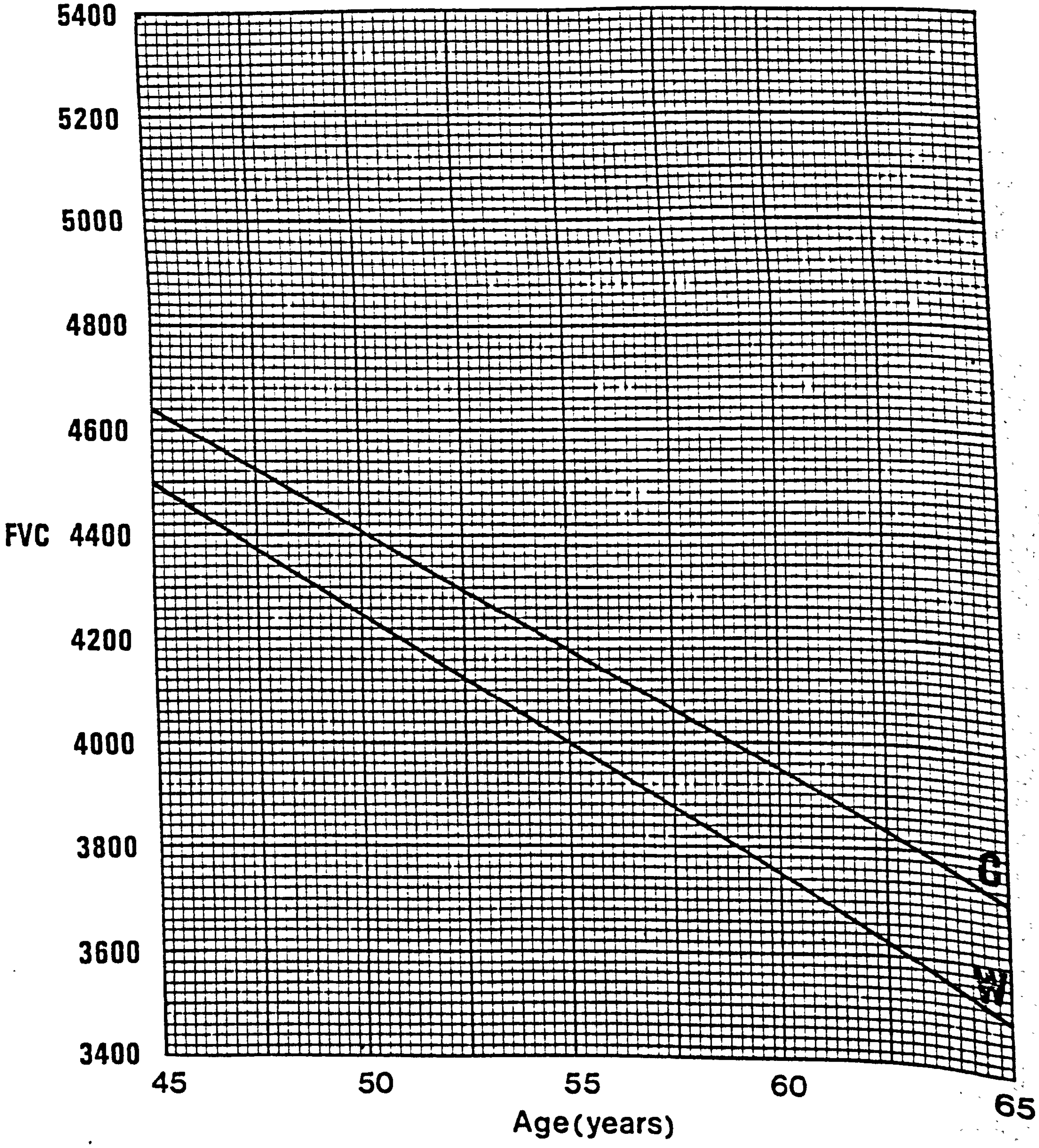


Figure D2 Two dimensional representation of relationship between FVC and age for welders and controls of height 1.70m (ignoring smoking habit)

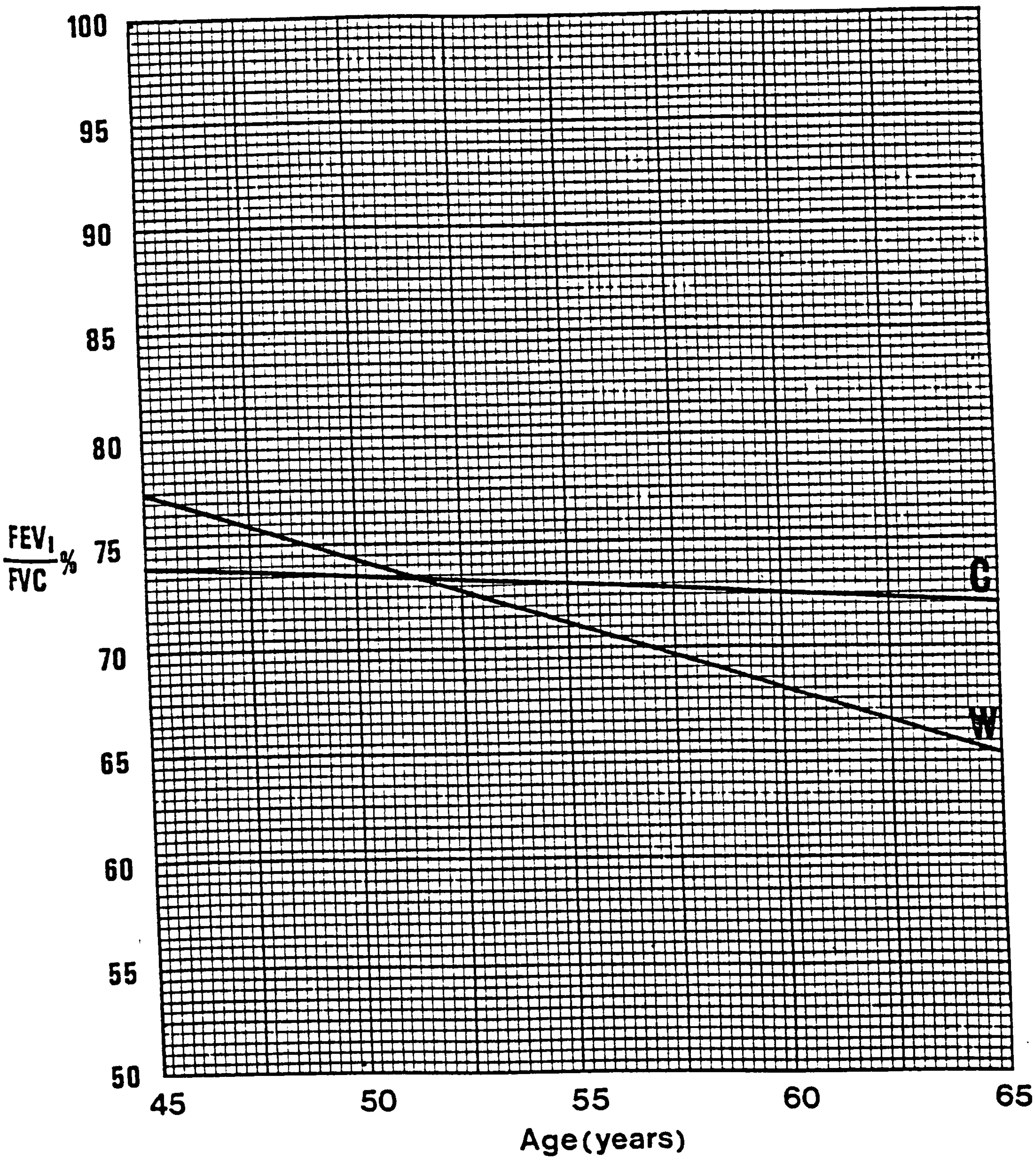


Figure D3 Two dimensional representation of relationship between $FEV_1/FVC\%$ and age for welders and controls of height 1.70m (ignoring smoking habit)

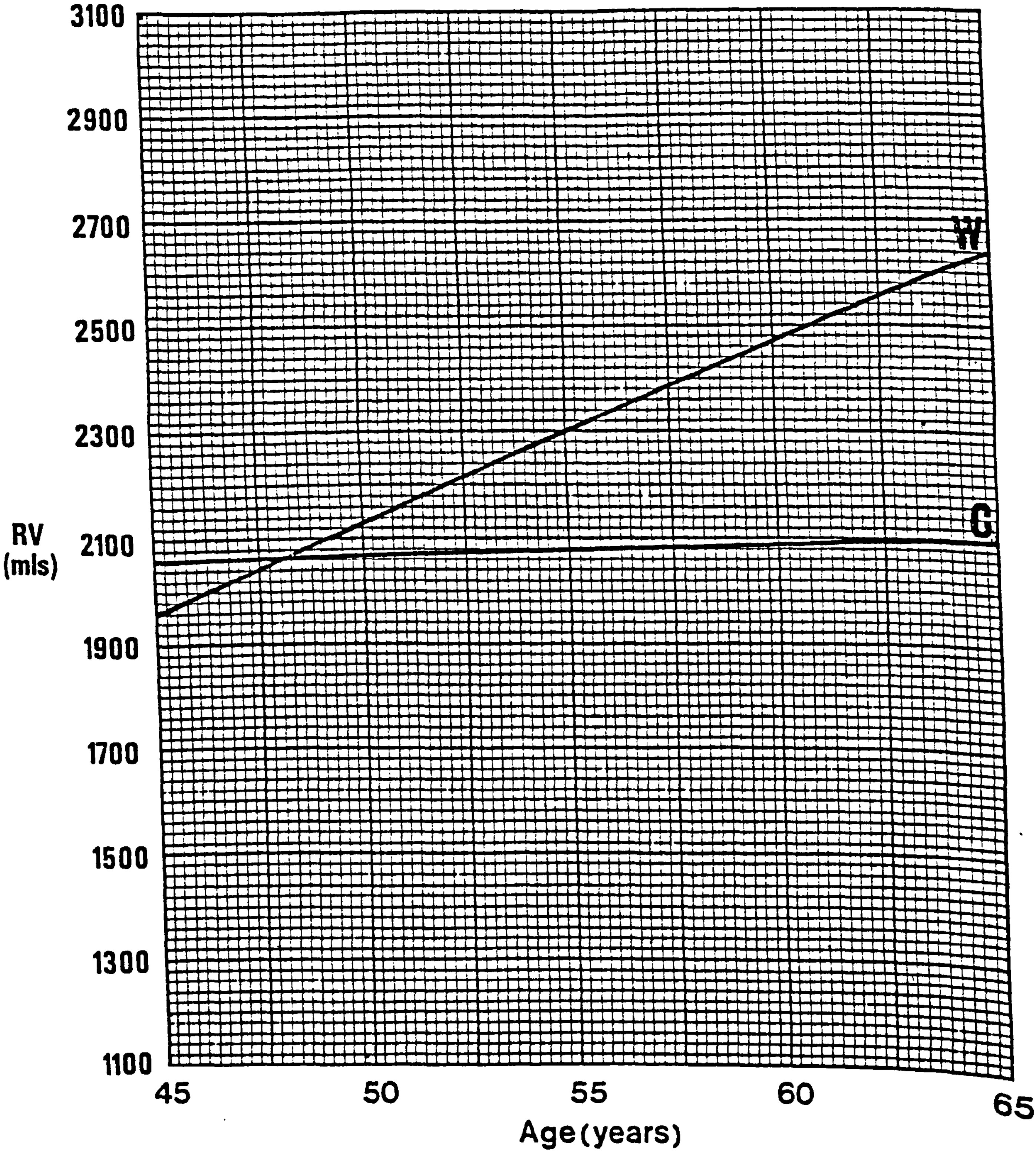


Figure D4 Two dimensional representation of relationship between RV and age for welders and controls of height 1.70m (ignoring smoking habit)

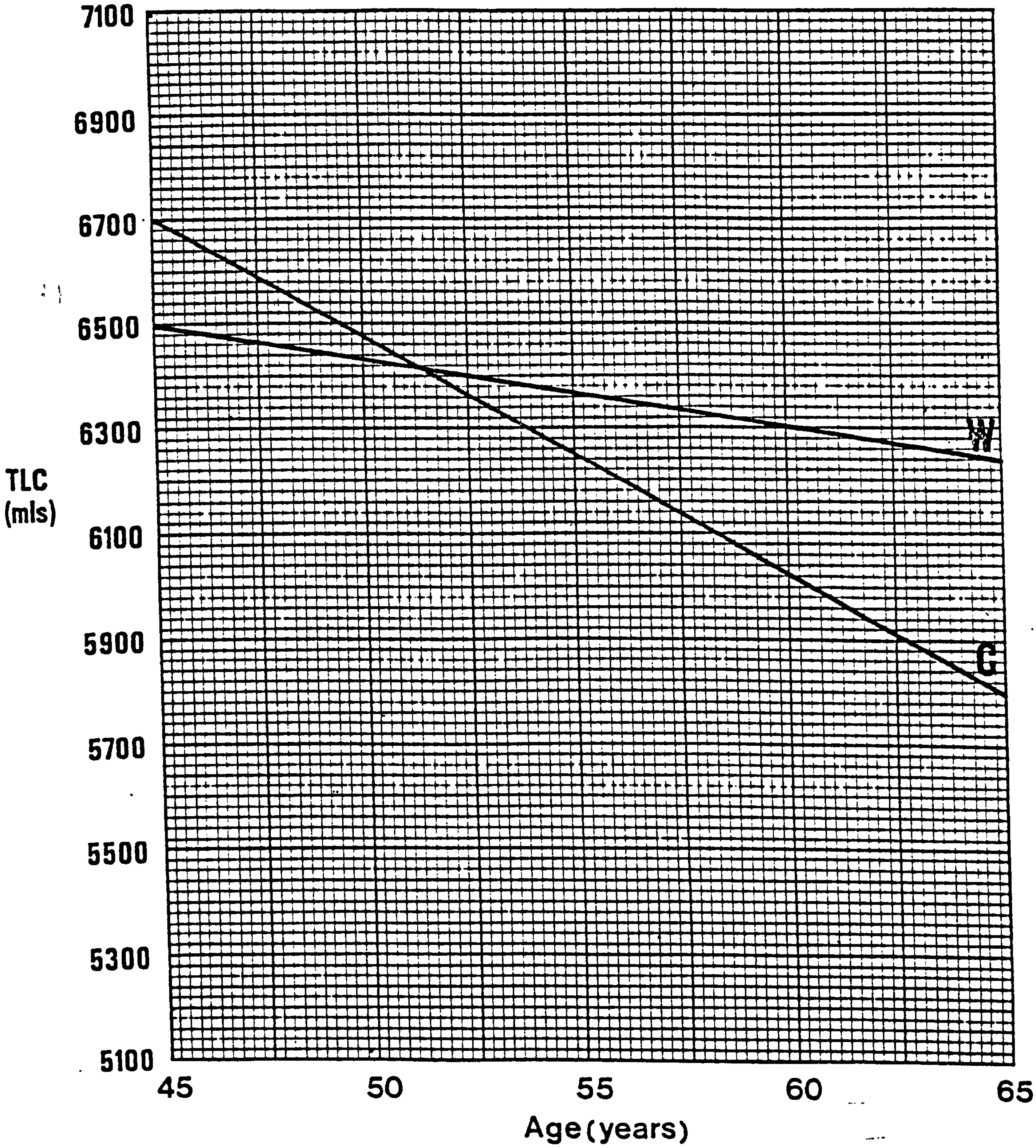


Figure D5 Two dimensional representation of relationship between TLC and age for welders and controls of height 1.70m (ignoring smoking habit)

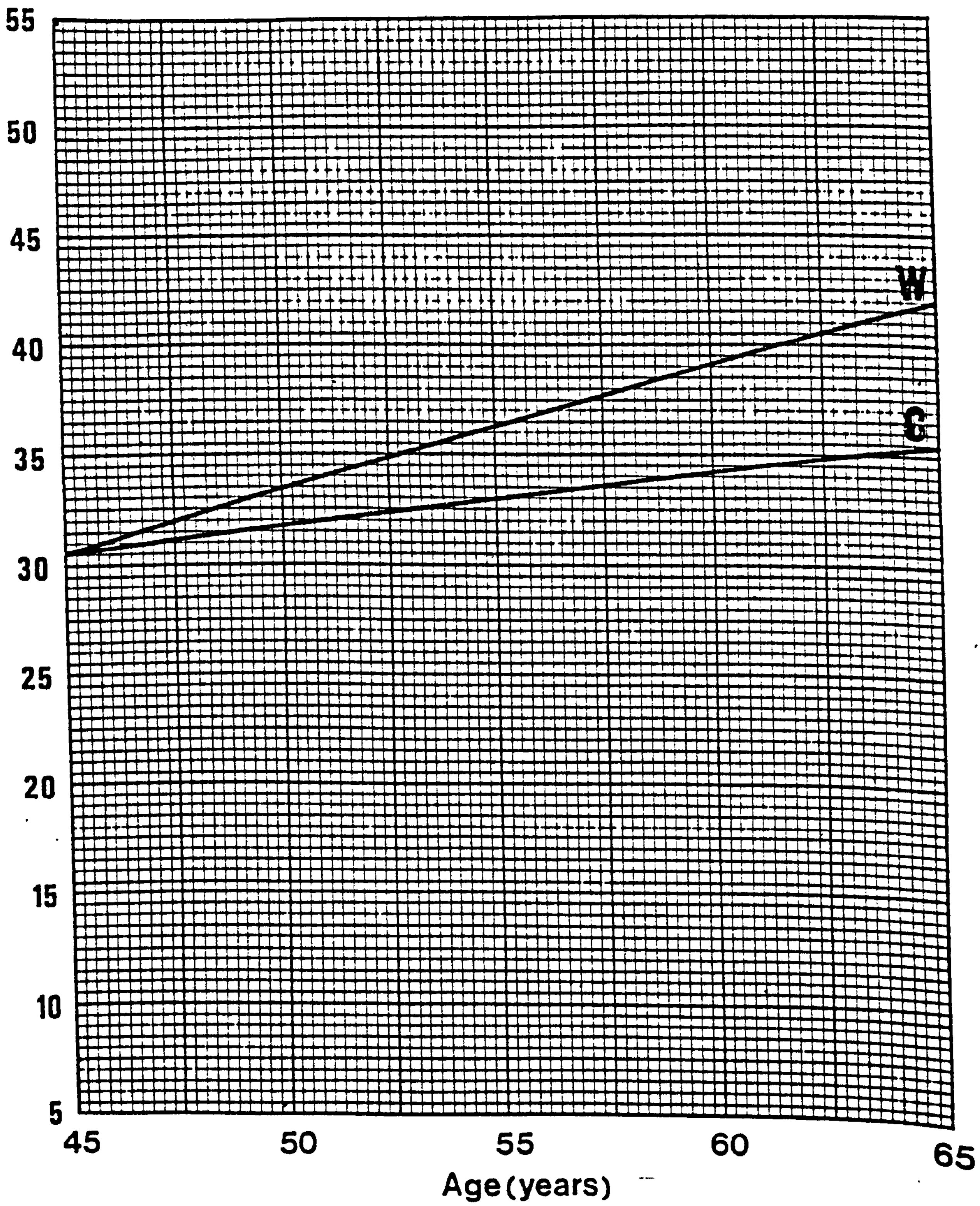


Figure D6 Two dimensional representation of relationship between $\frac{RV}{TLC}\%$ and age for welders and controls of height 1.70m (ignoring smoking habit)

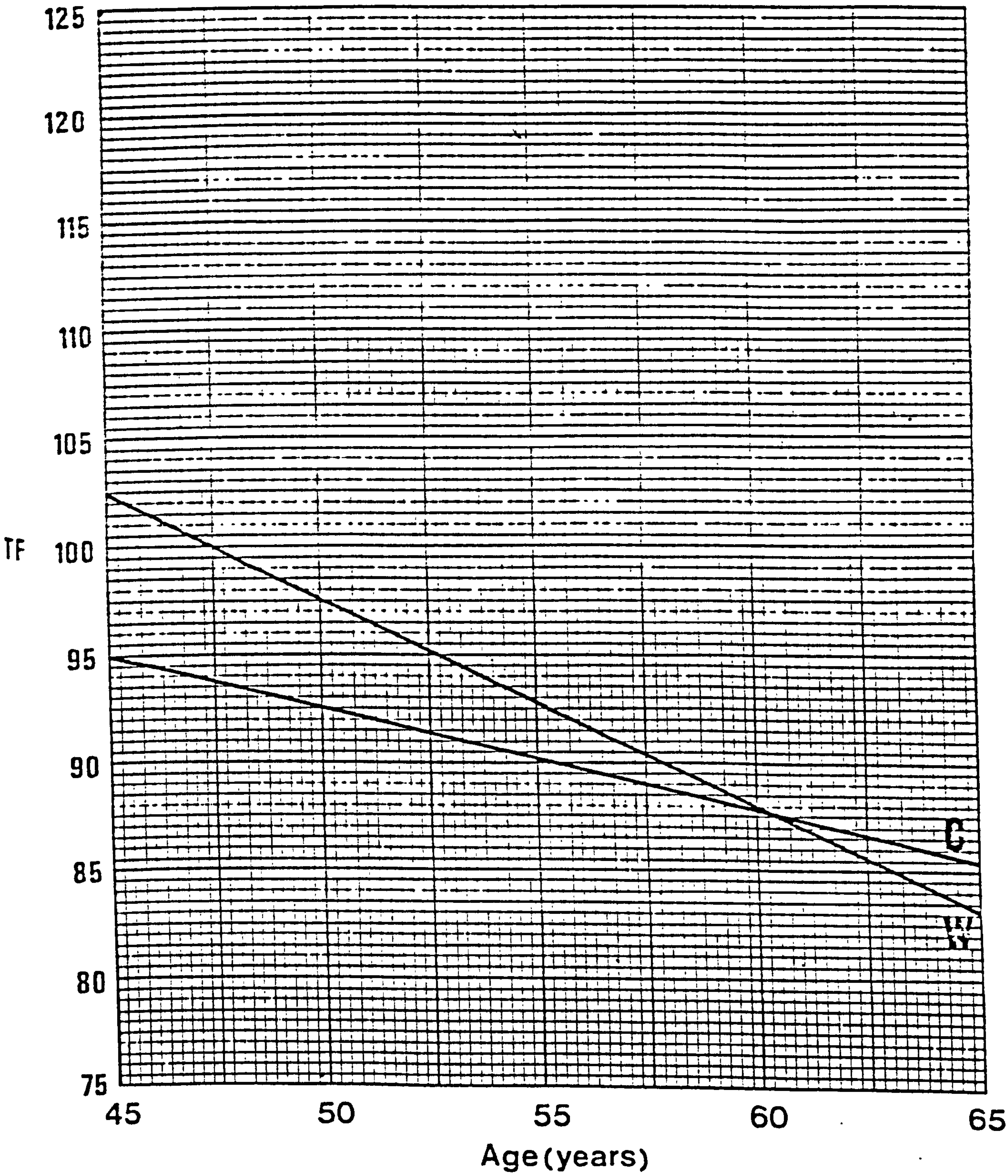


Figure D7 Two dimensional representation of relationship between TF and age for welders and controls of height 1.70m (ignoring smoking habit)

SECTION E

WELDERS' PERSONAL AND PROTECTIVE CLOTHING, AND INJURIES AT WORK

Summary

Welders employed at Her Majesty's Dockyards Devonport, Portsmouth and Chatham were interviewed about the personal and protective clothing they wore at work and the welding related injuries they had sustained. The incidence of welding related injuries treated at Medical Centres was determined by using a problem orientated injury record.

There was a high incidence of eye injuries, especially arc eye. Clear lens safety spectacles provide adequate protection against injury from slag chippings and are often worn by welders when chipping. There is evidence that clear lens prescription spectacles offer some protection from arc eye. There is no corresponding evidence for similar benefits from plano safety spectacles but this is thought to be because these are not worn except when chipping as other workers have demonstrated that safety spectacles are effective, at least in theory. Welders should be encouraged to wear safety spectacles at all times at work.

Many men had been burned frequently by the radiation of the arc, droplets of metal and/or hot slag. The general issue overall gives inadequate protection. A garment to counter the specified hazards of welding is required in a wide range of sizes. A flameproof garment was introduced in late 1981. Its design leaves much to be desired.

No welders wore a safety helmet, few wore ear defenders or used a respirator. These items and the head shield/filter lens holder should be compatible but those supplied cannot be worn together.

Although few foot injuries (excepting burns) were reported it was disturbing to find that many welders did not wear safety shoes or boots. The main reasons for this appear to be the extra cost of special footwear for work and the short life and discomfort of the reinforced toe-cap due to the welders kneeling or squatting.

INTRODUCTION

In addition to the general risks of injury of work in heavy industry welders face specific hazards related to radiation from the arc, hot metal droplets and chippings of slag. Ultra violet radiation may cause actinic conjunctivitis with or without keratitis ("arc eye") and, together with infrared radiation, induces erythema of exposed skin ("ray burn"). Hot metal spatter burns skin and/or clothing it falls upon.

An estimate of work related injuries to welders at HM Dockyards at Devonport, Portsmouth and Chatham has been made by collecting data at Medical Centres and interviewing currently employed welders about their injuries and the clothing worn at work. The results are presented.

MATERIAL AND METHODS

2.1 Medical records survey

Dockyard Medical Centre staff were requested to record all eye injuries treated in one year on a special form (McMillan, 1975., McMillan et al, 1976) and from 1978 to record injuries of all types on a problem orientated injury record card (McMillan, 1980). Following scrutiny of these records and re-questioning to eliminate errors and ambiguities they were analysed automatically to produce occupational injury rates for a variety of industrial processes and tasks.

2.2 Interview survey

In 1976-77, 328 welders at Dockyards at Devonport, Portsmouth and Chatham were interviewed about personal and protective clothing including eye wear, arc eye and burns (questionnaire at Appendix). The first 203 were questioned about personal clothing. This latter questioning was stopped as personal clothing sets were found to be very similar in men of the same age group. Results were coded, then analysed by computer programmes devised and operated by Dr Pethybridge, INM Alverstoke.

3. RESULTS

3.1 Personal clothing

Very few of 203 welders wore more than one layer of any single item of clothing (table E1), the exceptions being five men (2.5%) who wore two pullovers, two (1.0%) who wore two pairs of trousers and eleven (5.4%) who wore two pairs of socks. Less than half of those under 50 wore a vest while most over that age did. Almost everyone wore a shirt, trousers and socks. Some two thirds of men wore a pullover, more older than younger men. All 328 men were asked about footwear (figure E1). One hundred and seventy three wore safety footwear (46 shoes, 127 boots), 93 wore ordinary shoes, 67 ordinary boots, 7 wore wellington boots and one wore lightweight shoes used for athletic training. Safety boots were most popular with younger men.

One hundred and nineteen (36.3%) of 328 welders wore prescription spectacles at work (figure E2). A further twelve had distance spectacles but did not wear them at work lest they were damaged. Thirty two men wore spectacles only for reading. As would be expected the proportion of those with prescription spectacles for distance use increased with age.

3.2 Injuries at work and protective clothing

The number of work related injuries to welders reported as a result of them seeking treatment at a Dockyard Medical Centre is shown in table E2. There is considerable variation in the rate between Yards but a fair degree of consistency within each Yard. The rate at Devonport was about one per man each year. It was slightly less at Chatham and remarkably low at Portsmouth. Eye injuries were most common and there were relatively few foot and ankle injuries (table E3).

The eyes are the part of the body most commonly injured by welding processes (table E4) chipping slag causing foreign body injuries and the arc radiation causing actinic conjunctivitis.

Despite the obvious risk of foreign body eye injury during chipping slag only 35.5% of 328 welders wore safety spectacles at any time (figure E2). The proportion increased to age 40-49 years then remained fairly constant. Relatively few employees who were injured during chipping wore the eye protection which had been issued to them and even fewer of those who were assisting welders had been given any protection (table E5).

Arc eye is not uncommon in welders. At Devonport in one year welders comprised 32 (20.5%) of the 156 members of the Industrial workforce treated at Dockyard Medical Centres for arc eye. In all but one case the welder had been working at a weld when injured. Sixty nine (21.0%) of the 328 welders interviewed reported that they had had at least one episode of arc eye in the year prior to interview and 29 of these had more than one episode (table E6). Of the 69, 33 (10% of total) required medical treatment and 32 (9.7% of total) took time off work on at least one occasion (tables E7 and E8).

The incidence of arc eye was highest in the youngest age group falling to half that rate in those aged 30-39, rising to 26.2% to age 49 years then falling again to around 12% in those aged 50 and over (table E6).

It appears that welders who wear prescription spectacles are less affected by arc eye (table E9). Below the age of 50 years there are no statistical differences between those who wore no spectacles, those with prescription spectacles and those with safety spectacles but over the age of 50 years the prescription spectacle group has a significantly lower incidence ($X^2 = 7.91$, df2, $p < 0.05$).

With the exception of the youngest group, the hand held shield was more than twice as popular as the headshield (81.4% v. 39.6%) though many men interchange shields freely depending on their welding task. This changing pattern of usage precludes comparison of arc eye incidence in relation to head and hand held shields.

3.3 Other protective clothing

The various other items of protective clothing available to the welders are listed in table E10. Two hundred and twenty eight welders (69.5%) wore some form of head gear; 41 wore a leather skull or bump cap (a shallow peaked PVC cap with a metal or fibre glass plate protecting the skull) and 187 a cloth cap (often their own). The latter was especially vital to those who had thinning hair. Several had added a piece of cloth to the back of the cap to make a "kepi" protecting the neck. Not one wore a safety helmet. Almost every welder (93.6%) wore a boiler suit with virtually no variation with age.

One hundred and thirty one (39.9%) wore some form of leather clothing, arm sleeves and leather apron being the most popular and were favoured for overhead welding. Welders at Portsmouth and Devonport reported difficulty in obtaining leather clothing. Gauntlets (69.8%) were preferred to gloves (28.9%) especially with the younger men. Only about a third wore spats.

Seven per cent wore a heavy woollen Fearnought jacket and 8.8% wore a sweat rag round the neck. Only three ever wore ear defenders. The ear caps were easily damaged by sparks and stopped the helmet fitting effectively. Ninety six wore a respirator when working on galvanised or other zinc coated metal and 11 wore one working in tanks or other very confined spaces especially when the surfaces were oily or painted. One only wore a respirator when grinding. Two men were of the opinion that respirators trapped the fumes and made the situation worse! Welders expressed considerable reluctance to obtain fume extractors to remove fumes and gases. "It would take too long and we would never get the ships out".

3.4 Ray burn

Uncovered skin exposed to the radiation given off by welding may become erythematous, a condition the welder terms ray burn. Affected areas are listed in table E11. In general the incidence decreases with increasing age. The front of the shins and ankles are most commonly affected (21.6% of men) then the area of the neck and upper chest at the V opening of the unbuttoned collar of shirt and boiler suit (18.0%). Wrists (9.5%) and face or forehead (7.9%) are next commonly affected. A few have been burned behind the ears (1.5%), back of neck (1.5%) and/or chest (2.7%).

The incidence of ray burn of wrists, shins and ankles tends to increase with increasing height (table E12 and figure E13). The height of a significant proportion of men is not within the height ranges corresponding to the available sizes of coveralls (figure E4) but there are not constantly higher incidences of ray burn in these groups of men. Of the 219 who did not wear spats 42 (19.2%) had had ray burn of the shins or ankles while 29 (27.1%) of those who wore spats had had this injury but it is not known if spats were worn at the time of that injury.

3.5 Burns from sparks (hot splatter) or slag

Most welders have been burned by droplets of hot metal or by chips of hot slag. Some bear many scars of such injuries. The feet are most commonly affected (42.4% of men) (table E13) with the forearms a close second (37.2%). The upper arms (27.7%), chest (21.6%) and back of the neck (16.8%) are the other common sites. Burns inside the ear (3.7%) are relatively uncommon but particularly painful and dangerous. Overall there is no constant relationship with age, the only exception being the forearms where incidence decreases with age.

4. DISCUSSION

4.1 Very little has been published about the clothing welders wear and the injuries they receive. This paucity of information and the remarkable acceptance by welders that they cannot weld without being burned and that protective clothing cannot be comfortable serves to explain the high incidence of eye injuries and burns all over the body.

4.2 Personal clothing

Ross (1973a) questioned welders in a Scottish heavy engineering works about personal clothing and found that a relatively high proportion of men doubled up on items of clothing, eg two shirts, two pairs of trousers. He concluded that this was to afford extra protection against hot metal spatter. Very few Dockyard welders described such habits despite similar risks of injury. The explanation for this difference in behaviour is probably a combination of different climatic conditions, Scotland's Clyde Valley being generally colder than the South Coast of England, and the often inexplicable traditional behaviour within groups of workers.

4.3 Eye injuries and protection

The high incidence of eye injuries reported is not a problem unique to the Royal Dockyards. In America these form 49% of all injuries received by welders (US Bureau of Statistics, 1978). Arc eye is the most frequent type of eye injury. It is caused by ultraviolet radiation. The action spectrum of this radiation (the intensity of each wavelength necessary to produce a response) is known and welding irradiance levels have been studied in detail (Ferry, 1954., Emmett and Horstman, 1976., Horstman et al, 1976., Ingram and Horstman, 1977., Marshall et al, 1977). Many variables act simultaneously on the level and spectrum of the radiation which fluctuate from second to second as the welder works.

Emission increases with increased amperage and reduced fume and gas especially ozone, and decreases as the electrode is consumed. Increasing the temperature of the arc moves the spectrum towards the shorter wavelengths. Radiation emission varies with process being some 10-12 times higher with inert gas welding than with heavily coated electrodes. There is little or no radiation from submerged arc welding.

The welder's eyes are protected by a filter lens held in a helmet or hand held shield. The helmet should conform to British or National Standards and be compatible with other items of protective clothing; the latter is seldom achieved if a respirator or ear defenders must be worn. Filter lenses are red or green varying in darkness depending on the anticipated intensity of emission (British Standards 679, ANSI Z87). Thus the welder should change the filter lens according to the task he is to undertake choosing the lightest which will give adequate protection thus improving his vision of the task. However, very few welders studied by Ambrosi (1982) knew the shade number of the lens they used suggesting a need for greater appreciation of the available range and need to match shade to task.

The ultraviolet radiation causes abiotic changes in the corneal epithelium causing pain, photophobia, lachrymation and a feeling of grittiness (rather as if the eye had been sand papered). These symptoms appear after a short interval and seldom last more than 24 hours. There may be individual or racial variation in susceptibility (Gulvady, 1976). Cases are usually mild and keratitis much less common than conjunctivitis alone. Rarely there can be more serious injury as in the case described by Naidoff and Sliney (1974). A man stared into an arc for ten minutes and developed actinic conjunctivitis and photic maculopathy with a dense scotoma and peripheral field constriction. In six months he had normal visual acuity but a partially pigmented foveal lesion remained.

Although the injury is usually mild the man may be unable to work for the rest of the day or, if the symptoms keep him awake at night, he may not report the next morning. The amount of time lost throughout industry overall may be large as the incidence appears to have been and to remain unacceptably high (Kuhn, 1944., Fleischner, 1947., Ross, 1973b) though in the Dockyards it has been encouraging to note the relatively small proportion who lost time seeking treatment and/or recovering from symptoms.

Arc eye is usually caused by quite short exposure to UV radiation from the arc (US Bureau of Statistics, 1978) but less commonly it is from repeated over-exposure over several days as in the case described by Minton (1949) where the welder's filter lens was too small for its holder leaving gaps through which radiation passed.

The welder is more often injured by another welder's arc than by his own (US Bureau of Statistics, 1978). If he is working alone it is likely that he failed to bring his helmet down or raise the hand held shield before striking the arc or was working in a situation where radiation, either direct or reflected, could come round the shield into the eyes. Injury by reflection is becoming more common in the ship building and repair industries as aluminium is used more than in the past.

Failure to protect the eyes promptly may be because the filter lenses are so opaque that in many work sites which are poorly illuminated the welder cannot see the start point of the weld run if the helmet is in place and therefore he places himself at risk by striking the arc before putting the helmet and filter lens over his eyes. Tengroth (1976) considers that the safety margins afforded by these glasses are unnecessarily high, often by a factor of 10, and hopes to be able to construct glasses with 100% protection but with reasonably good visibility.

A filter lens made of a liquid crystal material has been developed recently. It is clear until the arc is struck but colours and filters radiation when activated by the arc via a photoelectric cell. The filter colour varies with the amount of radiation. The clear lens offers protection against foreign bodies during chipping. The apparatus is still relatively expensive.

Good illumination and carefully placed screens can make a very significant contribution to prevention if the welder takes the trouble to ensure these are provided.

As found in this study passers-by and those assisting welders are often injured by the arc's UV radiation. Physical barriers protect those in the vicinity but the usual solid screens can give the welder an uncomfortable feeling of isolation and this acts against him using them when he moves about a ship. Transparent coloured plastic curtains are available to protect passers by without isolating the welder as he can see what is going on outside the curtain. These curtains absorb the damaging wavelengths (Sherr, 1972). The welder should allow only essential workers to remain within the screens or curtains when he is welding and must ensure that those who do remain wear adequate eye protection.

Doig and Duguid (1951) and Ross (1973a) remarked on the decreasing incidence of arc eye with increasing age of the welder and attributed this to the older men taking more care. This relation of incidence and age was noted in the Yards. Ross also remarked on the low incidence of arc eye in men who wore prescription or safety spectacles. In the Dockyards men over 50 years who wore prescription spectacles had a significantly lower incidence than others over 50 years. A higher proportion of men over 50 years wear prescription spectacles than do younger men. It is thought that the low incidence is a combination of experience of age and the spectacles. There was no confirmation of Ross's observations about safety spectacles probably because the Yard welders tend to put on safety spectacles only when chipping and thus have no potential protection at other times when the filter lens shield is not in the working position.

Thus, despite the observations of Ross and of Horstman and Ingram (1979) who showed that clear lenses should offer significant protection, it is concluded that welders' assistants and those working close to the welder should wear a green lens safety spectacle or goggle and a suitable one is available in the Yards. Those working more remote from the arc, including the welder when not arcing, should wear a clear lens safety spectacle with side shields. An American Criteria Document (US Department of Health, Education and Welfare, 1972) suggests maximum exposure time for protection. By using these irradiance values and dividing them by measured emissions at the worksite a series of maximum allowable transmission values for protective lenses can be defined for different exposure times. If these transmission values are related to those of protective lenses suitable lenses can be selected. It has been suggested that those 8 feet or more from the welding operation do not need protection (Ingram and Horstman, 1977) but experience in the Yards does not support this.

Welders may wear contact lenses but must remove these whenever they think they have "caught a flash" as the lens over the injured cornea will cause increased irritation (Highgate, 1974., Carr, 1976).

The arc emits infra-red radiation which has caused denaturing of lens protein and cataracts in glass blowers and founders. No cases have been recorded in welders by most investigators (Doig and Duguid, 1951., Fogh et al, 1969., Gammal et al, 1973), but Ambrosi (1982) found a significant association between arc welding exposure and prevalence of lens opacities.

Welders also have a high incidence of foreign body eye injuries (McMillan, 1975., US Bureau of Statistics, 1978., Cape, 1979) due mainly to chipping slag. Once the welding run is complete a layer of slag will remain if a coated electrode has been used. They cannot see through the filter lens to chip this off and, unless the helmet has a flip-up lens holder with underlying impact resistant lens, he lifts the helmet and thus leaves his eyes unprotected. He should wear safety spectacles. Sometimes these slag particles are hot and cause corneal burns. Intra-occular injury is fortunately rare.

4.4 Skin lesions

The ultra-violet radiation causes skin erythema (Everett et al, 1965., Freeman et al, 1966., Gammal et al, 1973., Cape, 1979) and skin pigmentation

(Pathak and Epstein, 1971). The action spectrum has been defined for the erythema and pigmentation (Leach, 1970., Pitts and Tredici, 1971., Sliney, 1972., Gulvady, 1976). Infra-red radiation may contribute to the erythema.

The welders recognise the cause of the erythema and call it "ray burn". As found in the Dockyards it is very common especially at the V of the neck when the overall is unbuttoned, at the wrist and on the front of the shin when the welder is working seated or squatting and the trouser leg rides up.

Ray burn of the neck may be avoided by keeping the collar buttoned up (uncomfortable in such a hot situation) or by wearing a sweat rag round his neck. Many welders consider that the risk of this catching fire from sparks outweighs any advantages. Injury to the wrist, shin and ankle is more difficult as the sleeves and/or trouser legs must ride up when stretching, sitting and squatting. The increasing incidence of ray burn with height suggests that a wider range of sizes of shrinkproof overalls/boiler suits is required in the Yards. Longer socks and increased use of gauntlets may help.

Ray burn of the back of the neck and behind the ears is associated with reflected radiation, eg welding an aluminium mould for glass fibre ships where shiny aluminium is in front of and behind the welder. He must take special care to screen himself.

Other sources of UV radiation have been associated with skin cancer (Emmett, 1973 and 1975), actinic elastosis, phototoxic and photoallergic effects (Pathak and Epstein, 1971) but there are no reports of these effects in welders.

During welding, globules of molten metal spray off around the welder and may cause moderately severe burns especially if they lodge in footwear or in folds between skin and clothing especially at the belt. Almost all welders known to the author bear multiple small scars especially on the neck and upper chest and on the arms. The welders accepted the burns as an inevitable consequence of their trade and make light of all but the most serious.

In the Dockyards the feet are most commonly affected. Spats afford a certain amount of protection if the welder takes the trouble to wear them. Boots also give more protection than shoes but many welders persist in wearing shoes because, if a spark gets into a shoe it can be kicked off very quickly while a spark in a boot can burn for some time while the lacing is untied. A safety boot with quick release clasps appears desirable. Zips are unsuitable as they become welded by droplets of metal. Nylon socks must be avoided as these melt adding to the burn.

The high incidence of burns of the arms and chest should be rreventable by leather wear yet only 39.9% wore any form of this. The complaint that it is unavailable is not tenable because the welders could quickly resolve any deficiency by negotiation or industrial action. The real reason is the discomfort of wearing the cumbersome equipment in often restricted and hot areas.

Research is required to produce a non-restricting cool garment which can be marketed in large numbers and thus should be relatively cheap. It must give good skin coverage to protect the welder from heat, sparks and UV light, the material should be flame and heat resistant, sweat permeable and of a light colour, and the garment should be cut to protect the neck and allow the welder to squat and stretch without exposing skin. Pakkala (1980) has studied the suitability of various materials. Flame resistant wool and cotton and heat resistant synthetic fabrics including certain viscose rayons are useful as any burning continues for only a very short time. There is no melting and the charred material still gives protection. Wool and many synthetic materials with a slippery surface give best protection against molten metal. Flame resistant cotton is not as good. Protection from radiant heat depends on the reflection capacity of the surface, eg aluminized, the weight of the fabrics and the stability of their structure. In some situations special materials such as aromatic polyamides, and synthetic rubber may be needed (Anon, 1975).

Two other stigmata of the welder have been described, both related to spot welding in the motor vehicle industry. Jirasek (1979) describes disseminated rusty brown minute macules, varying in size, of irregular shape on the volar aspects of the unprotected arms and forearms upon which sparks fell during the spot welding process. Cape (1979) mentions this tattooing effect on the fingers which may be penetrated by the particles setting up an inflammatory reaction as a result of multiple foreign bodies and deep burning. No examples of these have been seen in Dockyard welders.

Foot injuries and safety footwear

It was disappointing to find that half the welders did not take the simple precaution of wearing safety shoes and boots with steel reinforced toe-caps in an environment in which the risk of foot injuries must be high. Surprisingly there were relatively few foot injuries reported to Medical Centres and many of these would have been burns. Many reasons were given by welders who wear ordinary boots and shoes. The most common reason was that with frequent kneeling the steel quickly wore through leather and that the back edge of the toe cap cut into the forefoot. Others emphasised the extra cost of safety footwear.

4.5 Head and hand held shields, respirators

Ross (1973a) found that most of his welders preferred a head shield while in the Dockyards most men prefer the hand held shield though many use both but separately. The design of the welder's shield may exercise a finite influence over measured breathing zone fume concentrations attenuating exposure by a factor of 2-10 (Moreton, 1974). A headshield is generally more effective than a handshield and a long headshield more effective than a short one. Some welders in the Yards were found to have extended the effective length of the headshield by adding a leather bib. Attenuation factors must alwyas be viewed with caution as the measured concentrations of fume within the welding helmet may be reduced by dilution by expired air from which pollutants have been "filtered" (White et al, 1975). The "dead space" of the helmet can cause an increase in arterial $_{p}CO_2$ as the man rebreathes an abnormally high proportion of CO_2 rich expired air. This increases respiratory rate and thus the amount of pollutant inhaled. The relative protective disadvantage of the handshield may be overcome by the welder standing further from the plume and batting it away from him.

In the Yards, there was a very real appreciation of the dangers of welding galvanised or otherwise zinc coated metal demonstrated by the number who wore respirators when this coating could not be removed before welding. The reluctance to wear respirators in the horribly confined spaces of tanks especially in the double bottoms of ships is readily appreciated and emphasises the need to ensure excellent ventilation supply and extraction.

In situations where hand held shields can be used a dust respirator with a nominal protection factor of 10 against particulates can often be worn (but seldom is in the Yards) and should give adequate protection against particulates in most circumstances but gives no protection against gases evolved during welding. In Britain the Health and Safety Executive (1978) issues a list of respirators approved for use in certain dusty industries and any of those approved under the Asbestos Regulations would be acceptable. It is possible for the air intake to be placed at the back of the wearer and this could provide an additional protection factor provided that it is not taking in air from a more contaminated area. This type of arrangement is usually used with power assisted respirators. When a welding headshield is preferred or required it should conform to the relevant British or National Standard and be compatible with other items of protective clothing. Few can accommodate an approved half or full face dust respirator. Specially commodious headshields are becoming available and are in use in North America. Compact disposable facemasks have improved in recent years and one version (the 3M Type 8800 Disposable Respirator) now has limited Health and Safety Executive approval against certain particulate matter.

There are a few welding helmets available in which a draught of clean air is delivered to the wearer's breathing zone, or from a source of compressed air (the British Oxygen Airchief and a similar product developed by Safety Products Ltd) which protect against gases and particulate. The British Oxygen Airchief gives a protection factor of about 3 (S. Silk, HSE, personal communication). Vorpahl and his colleagues (1976) have developed a similar shield acceptable to welders working in a workshop assembling battle tanks and giving 99% attenuation for hexavelent chromium.

Few oronasal cartridge respirators can be worn comfortably with prescription lens fashion spectacles.

Helmets with integral blowers and filters specifically adapted for welders' use are a recent innovation, for example the Racal Amplivox Airstream Welding Version AH2. This combines head, eye and face protection plus protection against welding fume (protection factor of 7) and ozone (but not other gases) in one unit which requires no external power or air supply. It is intended only for use in well ventilated areas.

These air supplied helmets are seldom suitable for difficult access work sites nor when welders prefer to use a hand held shield as do 30% of Dockyard welders. At Devonport filter respirators are used for only 6% of the total welding time (Holden et al, 1978). Ozone disintegrating filters are available for circumstances in which this gas is the main pollutant problem and no other suitable ventilation can be provided (Lunau, 1967).

In some circumstances for example, confined spaces, particularly with use of inert gases for shielding purposes, breathing apparatus which provides a source of uncontaminated air from cylinders or an airline may be required (Cimpoiesu, 1968).

4.6 Hearing protection

Welders may be exposed to high sound levels from their own processes, eg plasma arc produces high frequency noise at 110-120 dB(A) (Employment Medical Advisory Service, 1972., Spelbrink, 1976), or that of others such as iron caulkers using pneumatic tools. Rodin and his colleagues (1975) found perceptive deafness in 117 of 339 welders examined and considered that noise contributed significantly to this. Ross (1978) found that 33 of 926 welders had hearing losses which adversely affected social life. Many designs of head shields do not allow ear defenders to fit correctly (welders may trim the edges to fit round the muffs). This does not explain the alarmingly low number (3) of welders who wore ear defenders as the majority used a hand held shield. Many reasons were proferred, the most common being discomfort associated with sweating under the earpiece and repeated damage to the fluid or foam seal by hot molten metal. There was insufficient appreciation of the risk to hearing. This is being countered by a programme of audiometry and education in each Dockyard.

The absolute absence of wearing safety helmets is an alarming finding. The situation need for hard hats varies of course, 25% in US Labour Study. This must be countered by management and TU Officials enforcing regulations related to "Safety Helmet Areas" and providing helmets and welding shields which are compatible.

5. CONCLUSIONS

Although it is often possible to reduce arc radiation, hot spatter and slag at source they cannot be completely eliminated in most processes. As these cause significant numbers of injuries the welders and associated workers must be protected from them.

The need for improved protective clothing to be made available has been demonstrated by the reported injury rate. Coveralls permit ray burn, leather wear is cumbersome and reportedly often in short supply, headshields are not compatible with other protective equipment such as respirators and ear defenders.

The tacit acceptance of the inevitability of repeated minor burns and other injuries and their failure of many to wear suitable footwear is unlikely to stimulate action by management. The apparent lack of attention to detail in the design of the recently introduced flame resistant coverall and the failure to insist that welders use available protective equipment and acceptance of incompatible equipment suggest that a more vigorous management attitude to the pursuit of stated safety policies is required.

It is considered that urgent action is required to:-

a. provide, in a wide range of sizes, a well ventilated coverall with overlapping front closure using Velcro, a mandarin style collar, wide knee legs tapering to the ankles and fitted with loops to go under the foot, and buttoning cuffs manufactured in light coloured flame resistant shrinkproof cotton, treated to repel molten metal. Aluminised garments will be required in certain work situations.

b. provide a welding shield which incorporates or can be worn with a safety helmet, melt-proof ear defenders, and respiratory protection.

c. make welders contribute more to their own safety and that of others by using safety and ventilating equipment. This may be assisted by replacing solid screens with those of transparent material.

d. levels of illumination at welding sites should be increased and the least coloured suitable filter lens used so that the welder can see the workpiece through the lens and thus not have to run the risk of arc eye when striking the arc.

REFERENCES

ANON (1975)
Welder safety - a priority at Alvis
Metal Construction, September, 463.

AMBROSI, L. (1982)
Eye findings in arc welders.
Int. Inst. of Welding Document VIII-1011-82

AMERICAN NATIONAL STANDARDS INSTITUTE (1968)
American National Standard Occupational and Educational Eye and Face Protection. ANSI Z87.1.
Am. Nat. Stand. Inst. NY.

BRITISH STANDARD 154
Equipment for eye and face protection during welding.
British Standards Institute, London.

BRITISH STANDARD 679
Protective filters for use during welding and similar industrial operations.
British Standards Institute, London.

CAPE, J.C. (1979)
Health problems in motor vehicle manufacture.
Practitioner, 223,73.

CARR, C.F. (1976)
Contact lenses.
Occupational Health and Safety (ROSPA) 4,2,21

DOIG, A.T., and DUGUID, L.N. (1951)
The Health of Welders, HMSO London.

EMPLOYMENT MEDICAL ADVISORY SERVICE (1972)
Chief Employment Medical Advisers Notes of Guidance No. 59 Welding.
London. Department of Employment.

EMMETT, E.A. (1973)
Ultraviolet radiation as a cause of skin tumours.
Crit. Reviews Toxicol. 2,211.

EMMETT, E.A. (1975).
Occupational Skin Cancer.
J. Occup. Med. 17,44.

EMMETT, E.A., and HORSTMAN, S.W. (1976).
Factors influencing the output of ultraviolet radiation during welding.
J. Occup. Med. 18.1.41.

EVEREST, M.A., OLSEN, R.L., and SAYRE, R.M. (1965).
Ultraviolet erythema.
Arch. Derm. 92,713.

FERRY, J.J. (1954)
Ultraviolet Emission During Inert Arc Welding.
Ind. Hyg. Qu. March, 73.

FLEISCHNER, W.E. (1947)
Ophthalmic effects of welding radiation.
In: Proceedings of Conference on Industrial Ophthalmology, 221.
National Society for Prevention of Blindness, New York, Columbia University Press.

FOGH, A., FROST, J., and GEORG, J. (1969).
Respiratory symptoms and pulmonary function in welders.
Ann. Occup. Hyg. 12,4,213.

FREEMAN, R.G., OWENS, D.W., KNOX, J.M., and HUDSON, H.T. (1966).
Relative energy requirements for an erythemal response of skin to monochromatic wavelengths of ultraviolet present in the solar system.
J. Invest. Derm. 47,586.

GAMMAL, M.Y., SOLIMAN, A.M., and MUSTAFA, M.G. (1973).
Actinic conjunctivitis; the effect of ultraviolet and infra red radiation on the eyes of welders and glass blowers.
Bull. Ophthalmol. Soc. Egypt. 70,41.

GULVADY, N.U. (1976).
US Keratoconjunctivitis v. Established Dose Effect Relationships.
J. Occup. Med. 18,8,573.

HEALTH AND SAFETY EXECUTIVE (1978).
Certificate of Approval (Respiratory Protective Equipment).
London, HMSO.

HOLDEN, H.J., INGLE, J., MOLYNEUX, M.K.B., and GISBORNE, J.T. (1978).
Occupational hygiene study of Dockyard welding processes: a work situation survey report.
Institute of Naval Medicine Report No 45/78.

HIGHGATE D.J. (1974).
Contact lenses at work.
Occup. Safety and Hlth. 4,2,8.

HORSTMAN, S.W., EMMETT, E.A., and KREICHELT. (1976).
A field study of potential ultraviolet exposure from arc welding.
Weld. J. 55,1215.

HORSTMAN, S., and INGRAM, J.W. (1979).
A critical evaluation of the protection provided by common safety glasses from ultraviolet emissions in welding operations.
Am. Ind. Hyg. Assoc. 40,9,770.

INGRAM, J.W., and HORSTMAN, S.W. (1977).
A field study of near ultraviolet welding irradiance.
Am. Ind. Hyg. Assoc. J. 38,456.

JIRASEK, L. (1979).
Occupational exogenous siderosis of the skin.
Contact. Derm. 5,334.

KUHN, H.S. (1944).
Industrial Ophthalmology, London, Kimpton.

LEACH, W.M. (1970).
Biological aspects of ultraviolet radiations. A review of the hazards.
BRH/DBE 70-3 US Public Health Service, Bureau of Radiological Health, Rockville, Md.

McMILLAN, G.H.G. (1975).
A study of eye injuries and diseases at HM Dockyard, Rosyth.
M.Sc. (Occup Med) Thesis, University of London.

McMILLAN, G.H.G., DEACON, R., ANDREWS, A., BRANKIN, T.E. and JAMES, H. (1976)
The Naval Dockyards Eye Injury Study, Final Report.
Medical Research Unit, Devonport.

McMILLAN, G.H.G. (1978).
Occupational eye injuries - the changing pattern.
J. Soc. Occup. Med. 28,2,39.

McMILLAN, G.H.G. (1980).
Looking at problems - a new approach to injury records.
Occup. Hlth. June, 286.

MARSHALL, W.J., SLINEY, D.H., LYON, T.L., KRIAL, N.P., and DEL VALLE, P.F. (1977).
Non-ionising Radiation Protection Special Study No. 42-0312-77.
Evaluation of the Potential Retinal Hazards from Optical Radiation generated by Electric Welding and Cutting Arcs, December 1975 - April 1977. Special Study Report November 42-0312-77, US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD21020.

MORETON, J. (1974).
Safe Working and Welding Seminar.
Institute of Welding, Sheffield, 24 January.

NAIDOFF, M.A., and SLINEY, D.H. (1974).
Retinal injury from a welding arc.
Am. J. Ophthal. 77,663.

PAKKALA, L. (1980).
Work clothing and thermal comfort.
Fire technology Laboratory Report 23-25.4.
The Technical Research Centre of Finland (VTT)
International Institute of Welding Document VIII 906-80.

PATHAK, M.A., and EPSTEIN, J.H. (1971).
Normal and abnormal reactions of man to light, In Fitzpatrick, T.B. ed.
Dermatology in General Medicine, New York, McGraw - Hill Book Co. 977-1035.

PITTS, D.G., and TREDICI, T.J. (1971).
The effects of ultraviolet on the eye.
Am. Ind. Hyg. Assoc. J. 32,235.

RODIN, V.I., BOENKO, S.K., NECHIPORENKO, V.P. (1975).
Status of the hearing apparatus in electric welders.
Zh. Ushn. Nos. Gorlou. Botezn. July/Aug 1-4.
Read in English abstract.

ROSS, D.S. (1973a).
Welders' protective clothing - a pilot survey.
Protection 10,10,11.

ROSS, D.S. (1973b).
The short term effects on health of manual arc welding.
J. Soc. Occup. Med. 23,92.

ROSS, D.S. (1978).
Welders' health - non respiratory aspects.
Metal Construction, May, 204.

SHERR, A.E. (1972).
Plastics with selective wavelength absorption for safety and comfort.
Am. Indus. Hyg. 33,583.

SLINEY, D.H. (1972)
The merits of an envelope action spectrum for ultraviolet radiation exposure criteria.
Presented at 1972 American Industrial Association Conference, San Francisco May 18.

SPELBRINK, H. (1976).
Industrial medical aspects of welding procedures.
Schweissen u. Schneiden. 28,2,48. Read in English abstract.

TENGROTH, B. (1976)
Safety glasses in welding.
Environ. Res. 11,283-284.

US BUREAU OF LABOUR STATISTICS (1978)
Highlights of the welding and cutting accident survey.

US DEPARTMENT OF HEALTH, EDUCATION AND WELFARE (1972)
Criteria for a Recommended Standard Occupation Exposure to UV Radiation.
HEW Publication No. HSM 73-11009. US Govt. Printing Office, Washington DC.

VORPAHL, K.W., JORDAN, P.T., and MATHEWS, E.J. (1976).
Chrome alloy welding fume study.
J. Am. Ind. Hyg. Ass. 37,10.

WHITE, T., SCHUTZ, A., and LUNDGREN, K-M. (1975).
Effects of a welding helmet and dust respirator at rest and during exercise.
Scand. J. Work. Environ. Health. 1,249.

TABLE E1. Number (and percentage) in each age group of welders wearing listed items of personal clothing. (203 asked)

Items of clothing	Age (years)					
	20-29 n=17	30-39 n=25	40-49 n=75	50-59 n=59	60 and over n=27	All ages n=203
1 Vest	7 (41.2)	11 (44.0)	56 (52.3)	49 (83.1)	23 (85.2)	146 (71.9)
1 Shirt	16 (94.1)	23 (92.0)	71 (94.7)	59 (100.0)	25 (92.5)	194 (95.6)
1 Pullover	10 (58.8)	13 (52.0)	49 (65.3)	42 (71.2)	20 (74.1)	134 (66.0)
2 Pullovers	1 (5.9)	1 (4.0)	1 (1.3)	2 (3.4)	0 (0.0)	5 (2.5)
1 Pair trousers	16 (94.1)	23 (93.0)	74 (98.7)	58 (98.3)	26 (96.3)	197 (97.0)
2 Pairs trousers	0 (0.0)	0 (0.0)	1 (1.3)	1 (1.7)	0 (0.0)	2 (1.0)
1 Pair socks	15 (88.2)	22 (88.0)	65 (86.7)	54 (91.5)	26 (96.3)	182 (89.7)
2 Pairs socks	1 (5.9)	1 (4.0)	7 (9.3)	2 (3.4)	0 (0.0)	11 (5.4)

TABLE E2. Reported injuries to welders in three Dockyards 1978-1980

1978-1980	Devonport			Portsmouth			Chatham		
	1978	1979	1980	1978	1979	1980	1978	1979	1980
Number of injuries	208	266	232	52	45	66	64	56	64
Injury rate/100 men	87.4	100.0	95.8	34.9	27.2	51.1	62.7	50.0	75.2
Number of welders	238	266	251	149	165	130	102	102	84

TABLE E3. Injuries to welders in three Dockyards 1978-1980

Part of body	Devonport			Portsmouth			Chatham		
	1978	1979	1980	1978	1979	1980	1978	1979	1980
Eye	88	119	108	16	24	29	40	22	29
Ankle	4	5	9	1	2	0	2	2	0
Foot	14	14	13	2	3	4	2	4	2

TABLE E4. Total and eye injuries to Industrial personnel in three Dockyards 1978-1980 attributed to welding and associated processes.

Process	Total injuries	Eye injuries
Chipping slag	324	253
Welding	754	390
Assisting welder	377	278
Near Welder	333	291
Total	1788	1212
% Eye injury	-	67.8

TABLE E5. Failure to use eye protection when engaged in obviously hazardous situations in two Dockyards in 1975

Hazardous process	No. of eye injuries	Eye protection needed	Eye protection issued	Eye protection worn
Chipping slag	22	22	17	9
Assisting welder	103	101	38	14
Welding	15	15	12	9

TABLE E6. Number (and percentage) in each age group of 328 welders who suffered arc eye in the previous year

Number of episodes	Age (years)					
	20-29 n=44	30-39 n=36	40-49 n=107	50-59 n=109	60 and over n=32	All Ages n=328
1	7(15.9)	3(8.3)	20(18.7)	8(7.3)	2(6.2)	40(12.2)
2	6(13.6)	3(8.3)	5(4.7)	4(3.7)	1(3.1)	19(5.8)
3	2(4.5)	1(2.8)	3(2.8)	1(0.9)	1(3.1)	8(2.4)
6	1(2.3)	0(0.0)	0(0.0)	9(0.0)	0(0.0)	1(0.3)
8	1(2.3)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.3)
All	17(38.6)	7(19.4)	28(26.2)	13(11.9)	4(12.5)	69(21.0)

TABLE E7. Number (and percentage) in each age group of 328 welders who sought medical treatment for arc eye in previous year

Number of episodes	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All Ages
1	5(11.4)	2(5.6)	10(9.3)	3(2.8)	0(0.0)	20(6.1)
2	3(6.8)	2(5.6)	3(2.8)	1(0.9)	0(0.0)	9(2.7)
3	3(6.8)	0(0.0)	0(0.0)	0(0.0)	1(3.1)	4(1.2)
All	11(25.0)	4(11.2)	13(12.1)	4(3.7)	1(3.1)	33(10.0)

TABLE E8. Number (and percentage) in each age group of 328 welders who took time off work because of arc eye in previous year

Number of episodes	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All Ages
1	7(15.9)	2(5.6)	11(10.3)	3(2.8)	1(3.1)	24(7.3)
2	1(2.3)	2(5.6)	2(1.9)	1(0.9)	0(0.0)	6(1.8)
3	2(4.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(0.6)
All	10(22.7)	4(11.2)	13(12.2)	4(3.7)	1(3.1)	32(9.7)

TABLE E9. Number and percentage of welders under and over 50 years who suffered arc eye related to wearing of prescription or clear safety spectacles

Eyewear	Under 50 years			50 years and over		
	Arc eye		% with arc eye	Arc eye		% with arc eye
	Yes	No		Yes	No	
No spectacles of any type	30	65	32	8	30	21
Prescription spectacles only	6	17	26	2	50	4
Safety spectacles only	15	36	29	5	16	24

TABLE E10. Number (and percentage) in each age group of welders wearing listed protective clothing.

Protective clothing	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All ages
Leather or bump cap	6(13.6)	8(22.2)	12(11.2)	13(11.9)	2(6.2)	41(12.5)
Cloth cap	25(56.8)	22(61.1)	54(50.5)	65(59.6)	21(65.6)	187(57.0)
Safety helmet	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Boiler suit	43(97.7)	34(94.4)	97(90.7)	103(94.5)	30(93.8)	307(93.6)
Leather shoulder jacket	2(4.5)	1(2.8)	2(1.9)	4(3.7)	0(0.0)	9(2.7)
Leather half jacket	4(9.1)	1(2.8)	6(5.6)	2(1.8)	1(3.1)	14(4.3)
Leather full jacket	5(11.4)	6(16.7)	13(12.1)	5(4.6)	0(0.0)	29(8.8)
Leather arm sleeves	7(15.9)	10(27.8)	16(15.0)	6(5.5)	6(18.7)	45(13.7)
Long leather apron	6(13.6)	5(13.9)	12(11.2)	17(15.6)	3(9.4)	43(13.1)
Spats	11(25.0)	12(33.3)	33(30.8)	40(36.7)	11(34.4)	107(32.6)
Gloves	5(11.4)	10(27.8)	34(31.8)	32(29.4)	11(34.4)	92(28.0)
Gauntlets	34(77.3)	27(75.0)	75(70.1)	72(66.1)	21(65.6)	229(69.8)
Fearnought jacket	1(2.3)	2(5.6)	10(9.3)	8(7.3)	2(6.2)	23(7.0)
Sweat rag	4(9.1)	4(11.1)	12(11.2)	7(6.4)	2(6.2)	29(8.8)
Ear defenders	0(0.0)	0(0.0)	1(0.9)	2(1.8)	0(0.0)	3(0.9)
Respirator: galvanised	15(34.1)	9(25.0)	26(24.3)	37(33.9)	9(28.1)	96(29.3)
Respirator in tanks	2(4.5)	2(5.6)	6(5.6)	1(0.9)	0(0.0)	11(3.4)

TABLE E11. Number (and percentage) in each age group who reported having suffered repeated ray burn

Site of Ray burn	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All Ages
Face or forehead	5(11.4)	6(16.7)	9(8.4)	4(3.7)	2(6.2)	26(7.9)
Behind ears	0(0.0)	1(2.8)	1(0.9)	2(1.8)	1(3.1)	5(1.5)
Back of neck	0(0.0)	0(0.0)	3(2.8)	1(0.9)	1(3.1)	5(1.5)
V front of neck	17(38.6)	6(16.7)	18(16.8)	14(12.8)	4(12.5)	59(18.0)
Chest	1(2.3)	1(2.8)	3(2.8)	3(2.8)	1(3.1)	9(2.7)
Forearms	0(0.0)	2(5.6)	0(0.0)	1(0.9)	0(0.0)	3(0.9)
Wrists	4(9.1)	5(13.9)	11(10.3)	9(8.3)	2(6.2)	31(9.5)
Hands	1(2.3)	0(0.0)	3(2.8)	0(0.0)	1(3.1)	5(1.5)
Back of legs	0(0.0)	0(0.0)	1(0.9)	3(2.8)	0(0.0)	4(1.2)
Shins and ankles	11(25.0)	9(25.0)	40(37.4)	7(6.4)	4(12.5)	71(21.6)

TABLE E12. Number (and percentage) of welders who reported having suffered repeated ray burn of wrists, shins and ankles related to height

Site of ray burn	Height (cms)								
	<160	160-164	165-169	170-174	175-179	180-184	185-189	<189	All heights
Wrists	1 (6.7)	3 (10.3	3 (4.8)	7 (7.4)	8 (11.4)	6 (15.0)	1 (16.7)	2 (18.2)	31 (9.5)
Shins and ankles	2 (13.3)	5 (17.2	13 (21.0)	23 (24.2)	12 (17.1)	13 (32.5)	1 (16.7)	2 (18.2)	71 (21.6)
No. in height groups	15	29	62	95	70	40	6	11	328

TABLE E13. Number (and percentage) in each age group of welders who reported hot metal droplet or slag burns of listed parts of the body

Site of burns	Age (years)					
	20-29	30-39	40-49	50-59	60 and over	All Ages
Top of head	2(4.5)	1(2.8)	3(2.8)	2(1.8)	0(0.0)	8(2.4)
Inside ear	0(0.0)	2(5.6)	7(6.5)	2(1.0)	1(3.1)	12(3.7)
Face	0(0.0)	0(0.0)	3(2.8)	2(1.8)	0(0.0)	5(1.5)
Back of neck	9(20.5)	6(16.7)	21(19.6)	12(11.0)	7(21.9)	55(16.8)
Back	3(6.8)	3(8.3)	8(7.5)	7(6.4)	2(6.2)	23(7.0)
Chest	2(4.5)	9(25.0)	33(30.8)	18(16.5)	9(28.1)	71(21.6)
Shoulder	0(0.0)	0(0.0)	2(1.9)	5(4.6)	1(3.1)	8(2.4)
Upper arms	15(34.1)	15(41.7)	28(26.2)	26(23.9)	7(21.9)	91(27.7)
Elbow	6(13.6)	4(11.1)	13(12.1)	5(4.6)	5(15.6)	33(10.1)
Forearm	19(43.2)	16(44.4)	38(35.5)	41(37.6)	8(25.0)	122(37.2)
Wrist	4(9.1)	0(0.0)	3(2.8)	7(6.4)	3(9.4)	17(5.2)
Hands	1(2.3)	4(11.1)	8(7.5)	5(4.6)	2(6.2)	20(6.1)
Waist	3(6.8)	0(0.0)	5(4.7)	3(2.8)	1(3.1)	12(3.7)
Thighs	1(2.3)	2(5.6)	3(2.8)	2(1.8)	0(0.0)	8(2.4)
Ankles	5(11.4)	6(16.7)	12(11.2)	16(14.7)	2(6.2)	41(12.5)
Feet	15(34.1)	16(44.4)	54(50.5)	44(40.4)	10(31.3)	139(42.4)

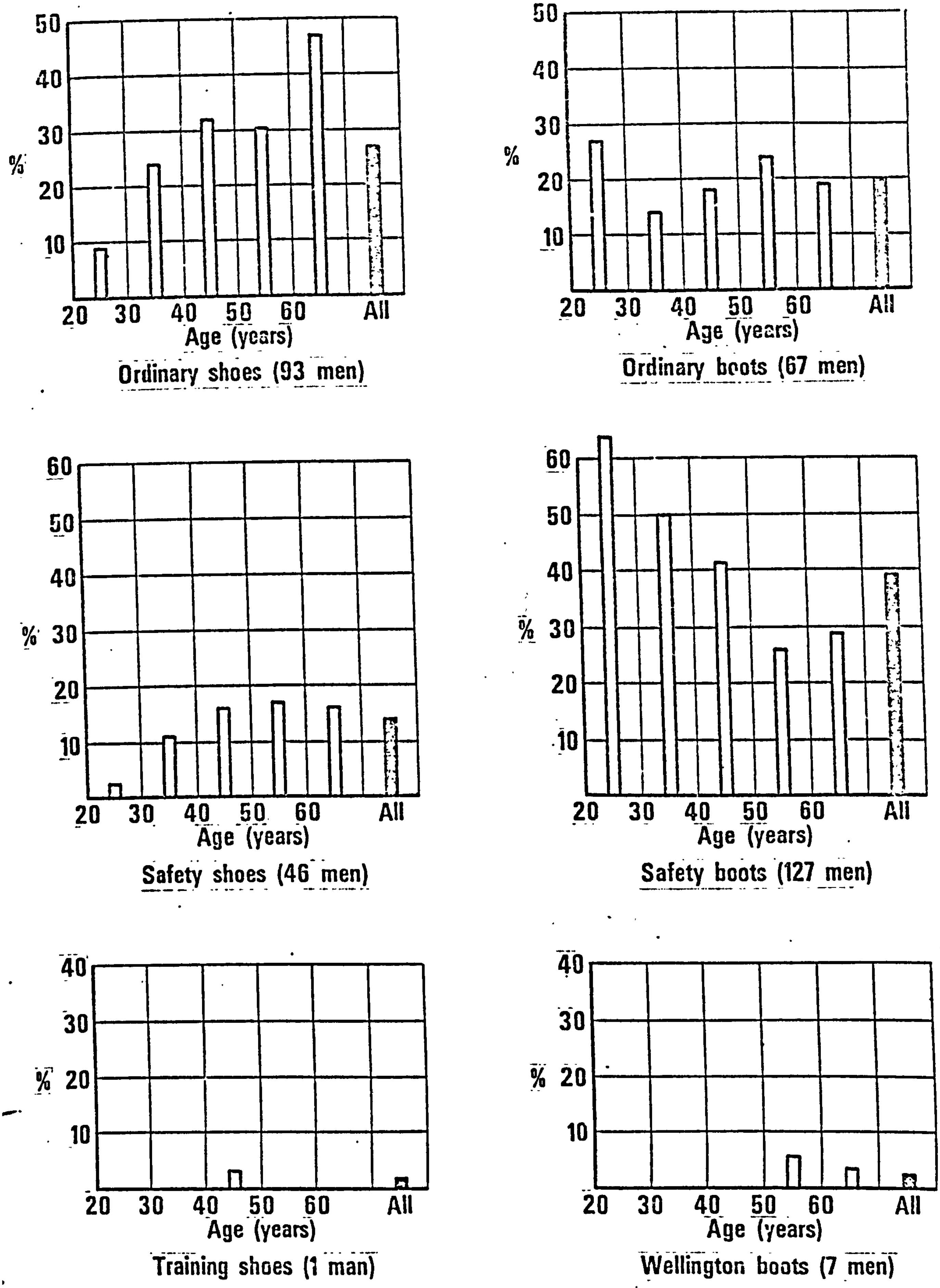
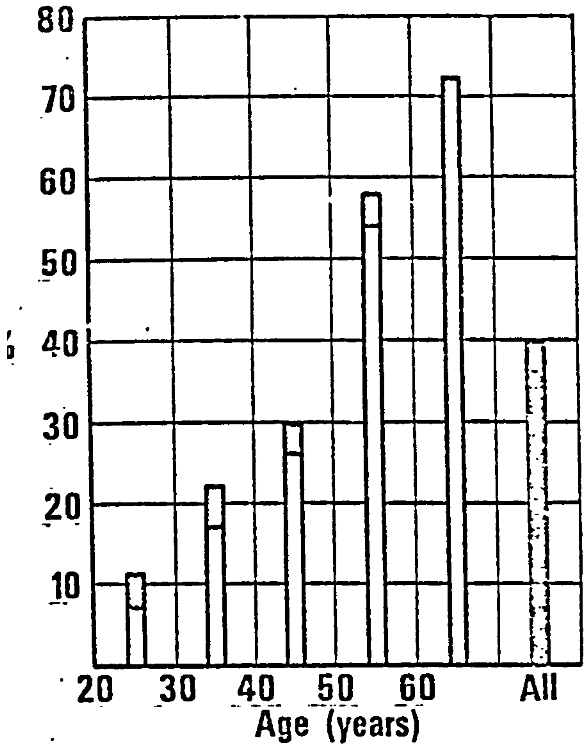
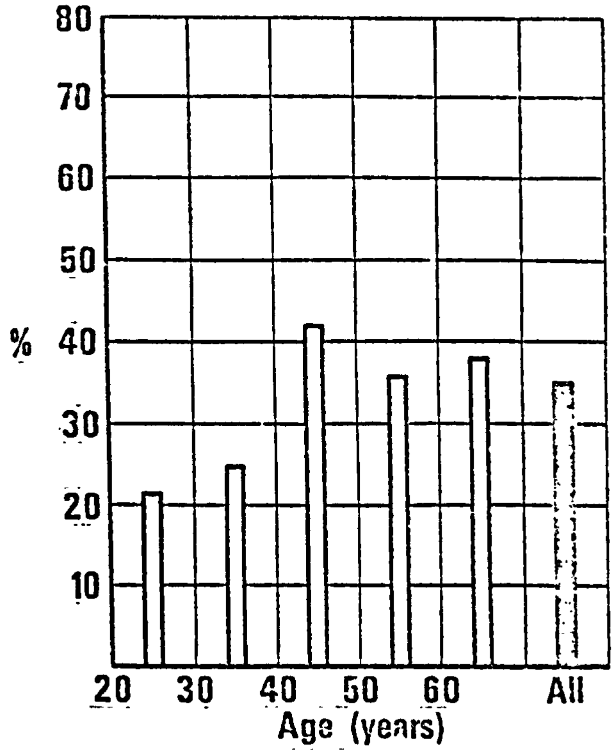


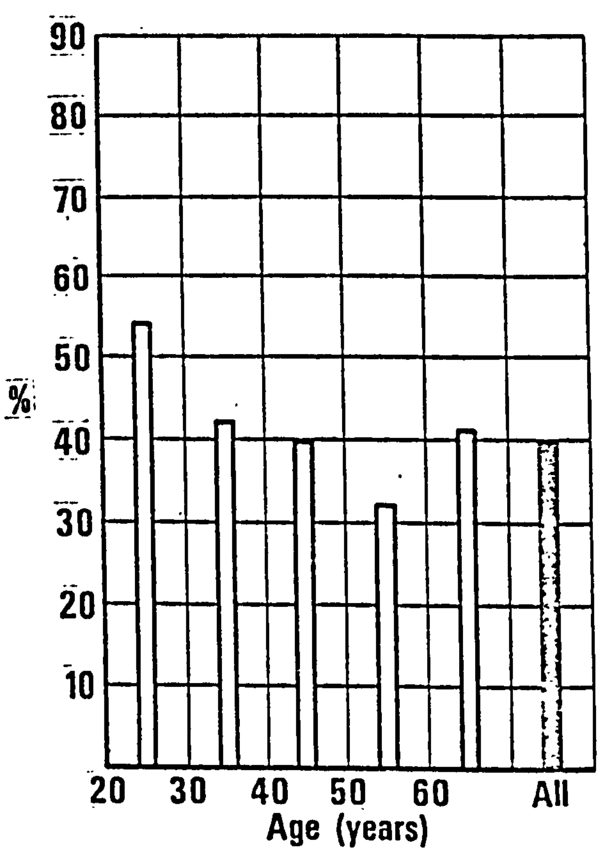
Figure E1. Footwear of 328 welders



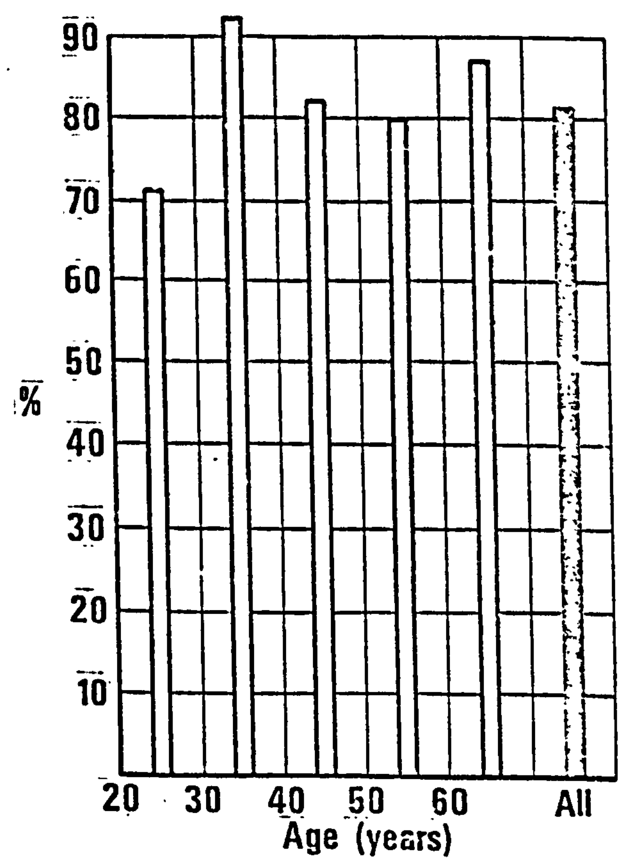
Prescription spectacles
At work (119 men) and
(shaded) not at work (12 men)



Safety spectacles (114 men)



Head shield (130 men)



Hand held shield (267 men)

Figure E2. Eyewear of 328 welders

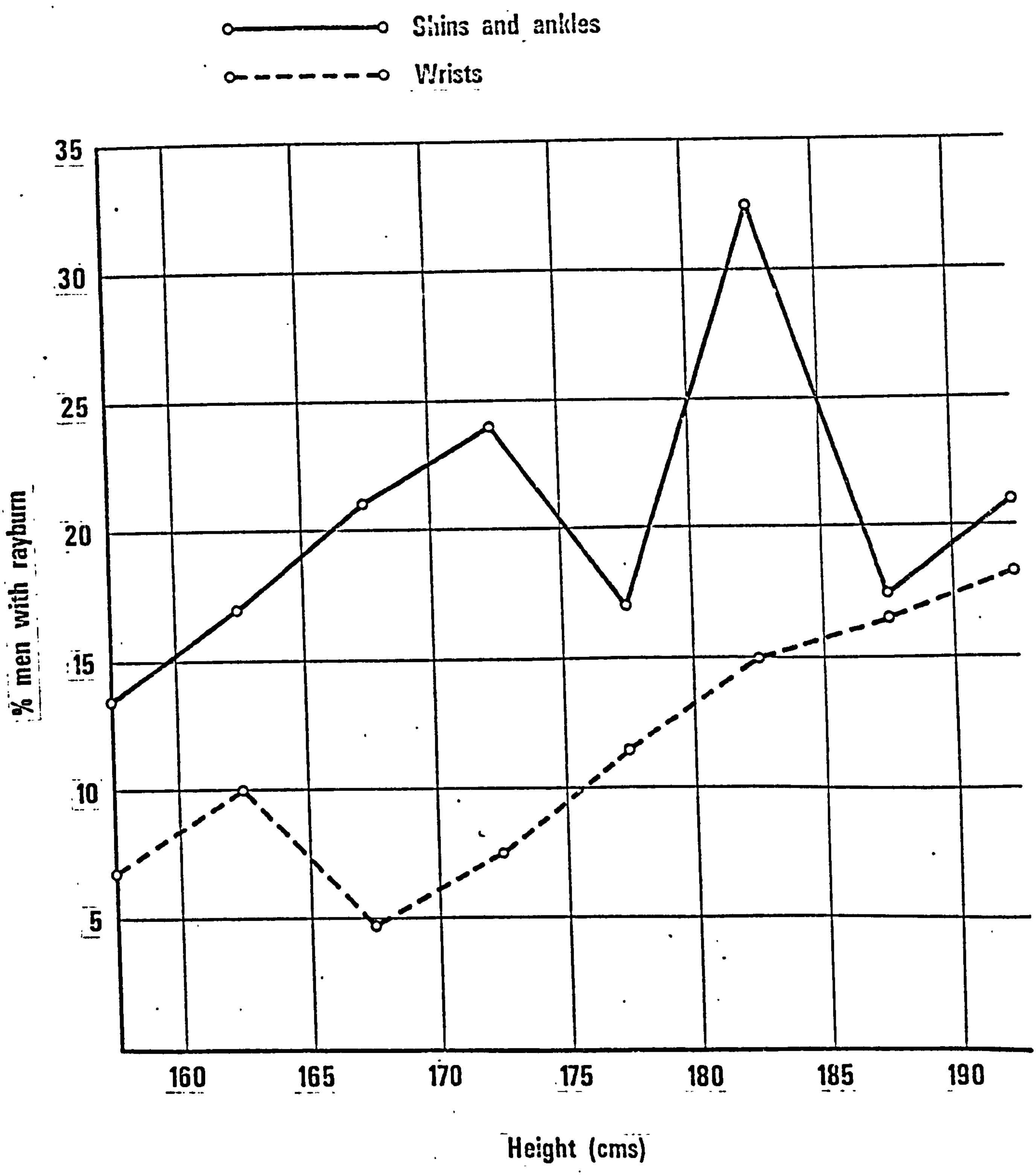
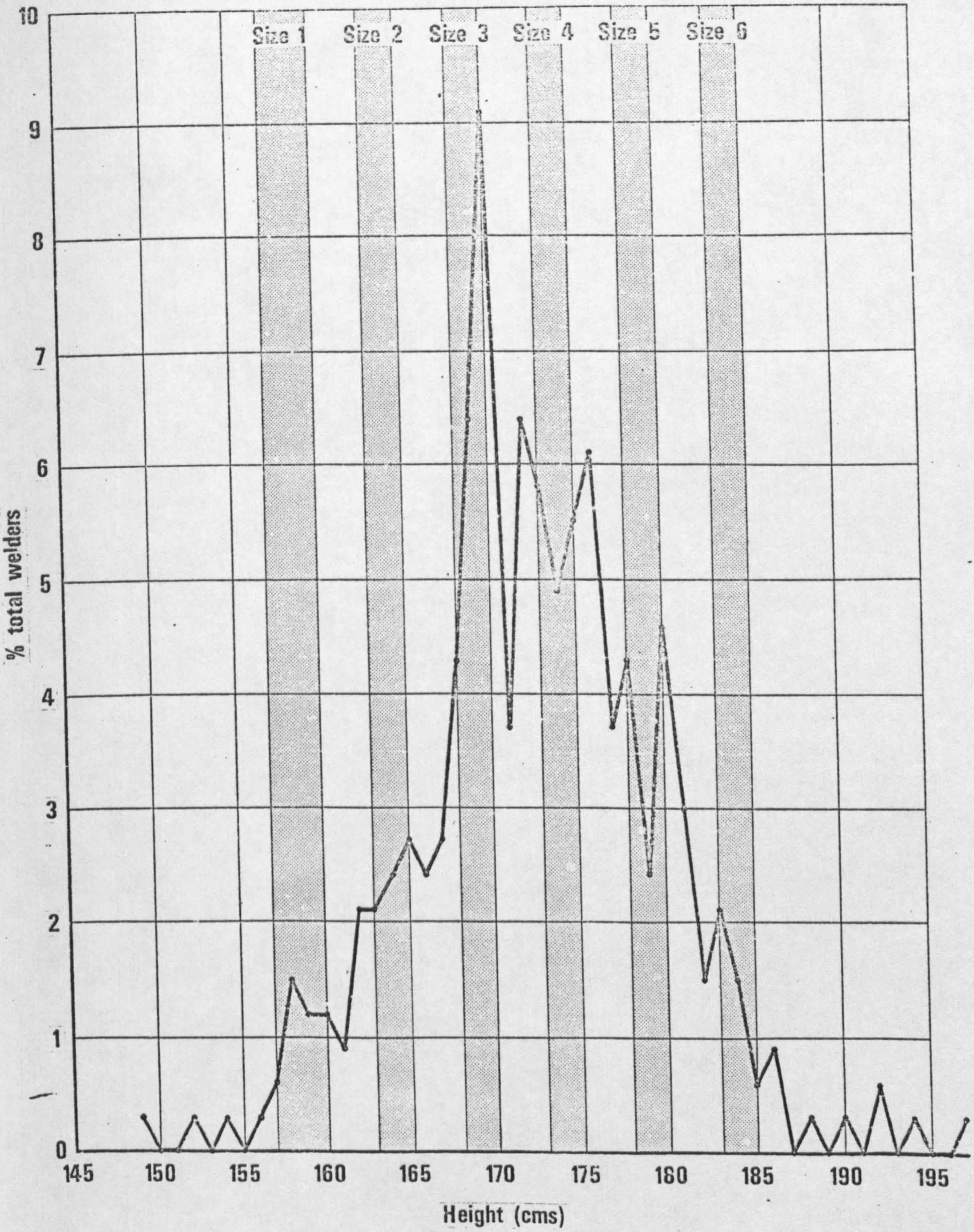


Figure E3. Incidence of rayburn of wrists, shins and ankles in 328 welders related to their height (cms)



No of men	1	2	12	29	61	98	72	42	6	4	1

Figure E4. Relative distribution of height (cms) of 328 welders related to height range for coveralls sizes 1-6 (shaded areas)

Cols

(Clin) MEDICAL IN CONFIDENCE | W | 0 | 6 | 1-3

No. | | | | | National Insurance No. | | | | | | | | | | 4-16

17-19

Names ....

Address ....

....

...rd Number .... Survey x-ray number | | | | | | 20-24

...al Health Service Number | | | | | | | | | | | | | | | | 25-40

...of Birth D M Y | | | | | | | 41-46

Name ....

Address ....

....

...of interview .... | | | | | | | 47-52

...he actual wording of each question. If YES, tick appropriate box.
In doubt record NO by leaving box blank.

...BLE: "I am going to ask you some simple questions about your chest.
Please try to answer the questions wherever possible as YES or NO".

ILLNESSES

	Age	Yes	
Have you ever had			
a. An injury or operation affecting your chest?	...	☐	53
b. Pleurisy?	...	☐	54
c. Pulmonary Tuberculosis?	...	☐	55
d. Bronchitis?	...	☐	56
e. Pneumonia?	...	☐	57
f. Any other serious chest illness? eg Asthma	...	☐	58

...GH

a. Do you usually cough during the day (or at night when on night-work)? If NO, go to 3. ☐ 59

b. Do you cough like this on most days for as much as 3 months each year? ☐ 60

...EGM

a. Do you usually bring up any phlegm from your chest first thing in the morning in the winter? If NO, go to 3c. ☐ 61

b. Do you bring up phlegm like this on most days for as much as three months each year? ☐ 62

c. Have you ever coughed up any blood? If NO, go to 4. ☐ 63

d. When was this? Record each year of occurrence ....

4. In the winter

a. Are you ever troubled by shortness of breath when hurrying on the level or walking up a slight hill? If NO, Grade 1. If YES, proceed to next question.

b. Do you get short of breath walking with other people at an ordinary pace on the level? If NO, Grade 2. If YES proceed to next question.

c. Do you have to stop for breath when walking at your own pace on the level? If NO, Grade 3. If YES, proceed to next question.

d. Are you short of breath on washing or dressing? If NO, Grade 4. If YES, Grade 5. Grade 1-5 [ ] 34

TOBACCO SMOKING (Tick box if YES)

8. a. Have you ever smoked? (This means as much as one cigarette or one small cigar a day, or one large cigar a week, or one ounce of tobacco a month for as long as a year). If NO, go to 10. [ ] 65

b. Do you smoke at present? [ ] 66

c. Have you given up smoking in the last month? [ ] 67

d. How old were you when you started smoking regularly? Age [ ][ ]

e. How many manufactured cigarettes do/did you usually smoke per day including the weekends? Number [ ][ ]

f. How much tobacco do/did you usually smoke per day including the week-ends in hand-rolled cigarettes? (Ozs p wk x 4 = gms per day) [ ][ ]

g. How much pipe tobacco do/did you usually smoke per week including the week-ends? (Ozs p wk x 4 = gms per day) gms [ ][ ]

h. How many small cigars do/did you usually smoke per day including the week-ends? Number [ ][ ]

i. How many large cigars do/did you usually smoke per week? Number [ ][ ]

EX SMOKERS ONLY

9. How old were you when you last gave us smoking? Age [ ][ ]

CHEST PAIN

10. a. Have you ever had any pain or discomfort in your chest? If NO go to 11 [ ] 52

b. Do you get it when you walk uphill or hurry? [ ] 53

c. Do you get it when you walk at ordinary pace on the level? If NO, go to 11. [ ] 54

d. What do you do if you get while you are walking? Stop or slow down = Y ie tick; Carry on = N ie blank [ ] 55

Record YES if subject carries on after taking Nitroglycerine (Trinitrin)

e. If you stand still what happens to it? Relieved = Y ie tick; Not relieved = N ie blank [ ] 56

f. If relieved - how soon? 10 minutes or less = Y ie tick; More than 10 minutes = N ie blank [ ] 57

11. OCCUPATIONAL HISTORY

Age	Employees Name	Job	Job Code	Start Year	Finish Year	Cols
						88-93
						94-99
						100-105
						106-111
						112-117
						118-123
						124-129
						130-135
						136-141
						142-147

Tick box when answer is YES

Do you or did you weld in the normal course of your work? (If YES go to question 14) — 148

Are you or were you exposed to welding fumes in the course of your work? — 149

How many years have you been welding or otherwise exposed to welding fumes? — 150-151

Those who have welded or still weld only

What type of welding do you usually do?

	Occasionally		Mainly	Cols
a. Metal arc (stick) welding		....		152-153
b. Tungsten inert gas welding (TIG)		....		154-155
c. Metal inert gas welcing (MIG)		....		156-157
d. Oxyacetylene		....		158-159
e. Other		....		160-161

Have you had ray burn in the last year? If NO, go to 21. — 0 — 162

How many times — 163-164

Which parts of your body, including your hands and feet, were affected? — Code — 165-168

....

....

How many times was it bad enough for you to go to your doctor or the Dockyard Surgery? — 169

How many times were you off work with it? — 170

		Cols
21. Have you had arc eye (flash) in the past year? If NO go to 25.	☐	171
22. How many times?	☐☐	172-173
23. How many times was it bad enough for you to go to your doctor or to the Dockyard Surgery?	☐☐	174-175
24. How many times were you off work with it?	☐☐	176-177
25. On what parts of your body including your limbs and face do you get hot metal or slag burns including small burns?	Code ☐☐☐☐	178-181
26. Have you ever had metal fume fever in the last year?	☐	182
27. If YES when and in what circumstances?	Code ☐☐☐☐	183-186
28. How many times was it bad enough for you to see your own doctor or the Dockyard Surgery?	☐	187
29. How many times were you off work with it?	☐	188

ASBESTOS EXPOSURE

30. Have you used asbestos cloth in preheating or to protect yourself and the work?	☐	189
31. Have you done any delagging or lagging or other work with asbestos - not just near others working with asbestos	☐	190
Type?		
When?		
32. Have you worked near others working with asbestos?	☐	191
a. Limpet spraying	☐	192
If YES, type of ships and approximate dates	☐☐ to ☐☐	193-1
b. Other asbestos work.	☐	197
Type of work?	☐☐	198-1
Approximate dates	☐☐ to ☐☐	200-

Items of protective clothing usually worn:

Item	Cols	Item	Cols
Head band welding visor/shield	204	Leather full length jacket (hip level)	214
Hand shield	205	Arm sleeves	215
Dark glasses	206	Short apron	216
Dark goggles	207	Long apron	217
Safety glasses	208	Long apron with splits down front and tied behind	218
Leather cap	209	Spats	219
Cloth cap	210	Safety shoes (steel toe caps)	220
Sweat rag	211	Safety boots (steel toe caps)	221
Leather shoulder jacket (to chest level)	212	Gloves	222
Leather half jacket (to waist level)	213	Gauntlets	223
		Respirator	224

4. Ordinary clothing usually worn at work

Item	Cols	Item	Cols
1 Vest	225	1 Pair socks	233
2 Vests	226	2 Pairs socks	234
1 Shirt	227	Boiler suit	235
2 Shirts	228	Ordinary shoes	236
1 Pullover	229	Ordinary boots	237
2 Pullovers	230	Wellington boots	238
1 Pair trousers	231	Any other items?	239
2 Pairs trousers	232	....	240
		....	241

5. Ordinary glasses at work? 242

6. Contact lenses at work? 243

General			Cols
	BP		244-249
√= Present	Clubbing		250
	Cyanosis		251
	Trachea	N = Normal Y = Abnormal: Note below	252
	Percussion	N = Normal Y = Abnormal: Note below	253
	Rales		254
	Persistent rales		255
	Rhonchi		256
	Pleural rub		257
	Other abnormalities - if YES, describe		258

LUNG FUNCTION ASSESSMENT AT CLINICAL EXAMINATION

		Actual	Predicted	Cols
Operator Code			FV Resp	259-260
Standing height (socks)			Cms	261-263
Weight (shirt and trousers)				264-266
FEV				267-272
FVC				273-278
FEV/FVC%				279-282
RV				283-288
TLC				289-294
RV%				295-298
TF				299-304
Mixing Index				305-307
Best curve first	MEF 50% VC			308-316
	MEF 25% VC			317-325

SECTION F

PROPORTIONAL MORTALITY STUDY OF WELDERS AND TWO CONTROL GROUPS

Summary

The mortality of welders and control groups employed for at least 6 months in HM Dockyard Devonport during a 20 year period has been studied using proportional mortality methods. It has revealed no evidence that exposure to welding fumes and gases is associated with increased mortality attributed to respiratory diseases or gastrointestinal or cerebral malignancies. There is evidence that occupational exposure to asbestos must be considered in studies of welders' deaths.

1. INTRODUCTION

The Registrar General's Decennial Supplement on Occupational Mortality (1970-72) specifies an occupational unit No. 036 "gas, electric welders, cutters, braziers". The standardised mortality ratio (SMR) for that unit for all cancers is 126, indicating an apparent excess of 26% over the general population. For circulatory diseases it is 127, respiratory disease 124 and cancer of the lung 151. The limitations of the data on which this analysis is based are discussed in this paper but, despite these, the need for further study cannot be ignored and thus the mortality patterns of men employed at HM Dockyard Devonport as welders, boilermakers, shipwrights, painters, electrical fitters and joiners over a twenty year period have been studied retrospectively and are reported. Apparent excess mortality for all and/or specific diseases especially malignant and non-malignant respiratory diseases has been found by other workers and their findings are discussed. Only one mortality study has been reported from Europe (Polednak, 1981).

2. MATERIAL AND METHODS

2.1 Population and records

Names and other personal identification factors including in most cases the National Insurance number of all welders, boilermakers, shipwrights, painters, electrical fitters and joiners, who had been employed for at least 6 months and had retired from or died while still employed at HM Dockyard Devonport between 1 January 1955 and 31 December 1974 were extracted from manuscript personnel files. All men were traced to determine which had died by 31 December 1975, OPCS undertaking the tracing of deaths in the retired men and providing copies of Certificates of Cause of Death for all men who had died. There were 656 deaths out of a total of 2568 men.

Age at death and the main cause of death were extracted from the certificates and the cause of death initially coded according to the ninth revision of the Manual of the International Statistical Classification of Diseases, Injuries and Causes of Death (WHO 1977) and then grouped as shown in table 1.

2.2 Statistical methods

It was not possible to calculate standardised mortality ratios as the total population at risk was not assessed. Instead,a proportional mortality ratio technique was employed, relative frequencies of specific causes of death in welders, control group 1 (boilermakers and shipwrights) and control group 2 (electrical fitters, painters and joiners) were obtained and compared to "expected" numbers based on the cause specific proportional mortality of the 656 deaths in these 3 groups. This allowed comparison of mortality in welders with these other craftsmen of the same social class who had moderate intermittent exposure to welding fumes and gases (control group 1) and who had little or no exposure (control group 2).

The expected number of deaths from each cause (age-adjusted by the indirect method) and the significance of its difference from the observed number were determined by the Mantel-Haenszel procedure (1959). The steps used to evaluate each cause of death were:-

a. Construction of a series of age-specific (5 or 10 year gands) 2 x 2 contingency tables

	Number of deaths in age group attributed to:-		
	(i) Specified cause	(ii) Other causes	Total deaths
Specified group	A_i	C_i	N_{1i}
Other groups	B_i	D_i	N_{2i}
Total	M_{1i}	M_{2i}	T_i

b. calculation of the expected number of deaths among the specified groups in the age group i

$E(A_i) - \frac{N_{1i}M_{1i}}{T_i}$ and its variance $V(A_i) = \frac{N_{1i}N_{2i}M_{1i}M_{2i}}{T_i^2\ (Y_i-1)}$

c. summation over the age groups of the observed numbers, the expected numbers and the variances;

d. calculation of the continuity-corrected chi-squared value with one degree of freedom $X^2 = \frac{\left[\left|\sum A_i - \sum E(A_i)\right| - 0.5\right]^2}{\sum V\ (A_i)}$ as detailed by Mantel and Haenszal (1959).

3. RESULTS

3.1 Population

There were 2568 men in the study population; 131 welders, 1442 in control group 1 and 995 in control group 2. Six hundred and fifty six men had died; 52 welders, 395 control group 1 and 209 control group 2.

3.2 Causes of death

A summary analysis of cause of death is given in table 1. Overall, cardiovascular system disease accounted for 57% of the 656 deaths, respiratory disease 22%, gastro-intestinal disease 11%, urogenital disease 4% and all other causes 6%. Specific causes of death accounting for more than 5% of all deaths were myocardial infarction (34%), cerebrovascular thrombosis or haemmorrhage (11%), cancer of the lung (19%), congestive cardiac failure (5%) and chronic bronchitis/asthma/emphysema (5%).

In several cause of death categories the observed and expected numbers of welders are very small and in these cases very little or no emphasis can be attached to the proportional mortality ratios nor the chi-squared values. In the welders the number of respiratory deaths is just less than expected. There was only one death from bronchitis and none from pneumonia.

Respiratory malignancy was the commonest cause of death in the respiratory system; five carcinomas of bronchus and three pleural mesotheliomas. The latter plus one case of asbestos induced parenchymal fibrosis gave a total of four deaths directly attributable to asbestos. There were no sinonasal tumours - a site of election for nickel induced malignancy.

In the welders, deaths due to gastro-intestinal diseases was the only grouping showing a significantly ($p<0.05$) higher number of deaths than expected on the basis of the proportional mortality experience of all three groups. However, the lesions were in various parts of the gastro-intestinal tract. Cardiovascular disease, and myocardial infarction in particular, accounted for more deaths than any other cause. Only two deaths were due to central nervous system disease and neityer was due to cerebral neoplasia.

4. DISCUSSION

4.1 Methods

There are advantages and disadvantages to all epidemiological and statistical methods of comparing mortality patterns in different groups. Use of general population mortality rates to estimate the mortality to be expected in employed groups is subject to considerable bias (the general population contains the chronically sick and the aged) and selection for health even after long follow-up periods. For example, risks of occupational cancer would tend to be under-estimated (Goldsmith, 1975).

Membership in an exposed or non-exposed group is the result of a large and complex series of non-random events and some of these can influence the risk of death or disease. Fox and Collier (1976) consider three factors which may exert an important influence in industries which are said to carry little or no risk to health as they have low mortality rates.

The first is the healthy worker effect which has been considered by them and by McMichael (1975). To be employable in an industrial workforce an individual must usually be relatively healthy and active. Therefore, in an industry free of significant life-shortening hazards, death rates within that workforce will be less than in the general population. Individuals whose health does not meet the requirements of the industry do not enter it. Fox and Collier have shown that the healthy worker effect can persist with decreasing influence for up to fifteen years after the person has left the industry and therefore one expects to find a carry over into the retired segment of the worker population and this must be included in the mortality cohort as has been done in this study.

Secondly, those whose health deteriorates below the required level may not remain in the industry, therefore those remaining are a survivor population. In at least one industry those who left had a higher mortality ratio than those who remained, the differences being greatest in the age range 25-44 years and for lung cancer and other respiratory diseases. This is a very difficult effect to measure as it is continuously altered by the dynamic movements within and out of industry. Although most people who change jobs do so for reasons unrelated to health there is a number who change because they are not fit enough to continue in their present job or possibly because they consider that their own employment is affecting their health. Some aspects of this in Dockyards welders have been studied earlier (McMillan and Molyneux, 1981) and it has been shown that respiratory diseases have not been in excess as reasons for selected employment or medical retirement nor have a disproportionate number of welders left the Yard. In this study the difficulty has been reduced by including discharges in the mortality cohort.

The third factor is the length of the follow-up. Retrospective studies give one a notable advantage in this respect but have disadvantages in that one must be content with the quantity and quality of the data which is available. For example, in this study comparison of respiratory and cardiovascular death rates would have been more complete if details of smoking habits during life had been available. It is also impossible to relate the death rates to the welders' exposure to fumes and gases arising from the welding processes although from the earlier studies (Holden et al, 1978) it can be deduced that the vast majority of welders used manual metal arc welding on mild steel. These and other disadvantages could have been overcome in a prospective study but information on possible ill-effects of welding is required now rather than twenty years on.

Redmond and Breslin (1975) recommended the use of relative risk or standardised mortality ratios based on an internal population but considered an internal proportional mortality ratio an acceptable alternative. However, the latter choice does mean that if the mortality in a sub-group is markedly greater than in the total work population only the more pronounced deviations from expected will be shown to be significant and a further bias will appear whenever a common cause of death is over or under-represented. The main advantages of the proportional mortality ratio are that denominator populations are not required (and in this case were not available) and that the control population can be more relevant to the case group as in this study.

Proportional mortality ratio is a statistic summarising the information from all age groups and thus age specific changes may be obscured. The data have been scrutinised to see if there were large discrepancies between the observed and expected in any age group.

The study is hindered by relatively small numbers of deaths, a function of the number of men employed and the time lapse between the end of the study catchment period and analysis. Numbers could have been increased either by extending the study to the other Dockyards but resources were not available to do this, or by extending the period to before 1955 but this was not feasible because of the unusual working conditions of that period. In the post-war decade work in the Yard decreased from the war levels, men were returning to take over work which had been done by women and the Yard was considerably overborne with an imbalance of the number of men in different crafts. Shipwrights were especially affected. To avoid massive discharges men were deployed to work which was not usually within their craft. Many shipwrights became "brush hands" doing relatively unskilled painting jobs. The painters in this study are all trained skilled craftsmen. By 1955 a more balanced workforce had been achieved in the Yard, had settled down and once again men were working at their crafts.

4.2 Causes of death

There is no evidence from this study of an excess of respiratory deaths which could be attributed to the effects of fumes and gases arising from welding processes at Devonport.

While this is in accord with the opinion that, in general, welding is not associated with an increased risk of malignancy (Challen, 1974., Wilhelmsen et al, 1977., Hedström, 1979) other published studies have shown an excess risk of lung cancer in welders (Breslow et al, 1954., Dunn and Weir, 1968., Menck and Henderson, 1976., Milham, 1976., Blot et al, 1978., Decoufle et al, 1978., Redmond et al, 1979., Beaumont and Weiss, 1980., Blot et al, 1980., Petersen and Milham, 1980., Sjögren, 1980., Polednak, 1981.).

The explanation of these differences may be related to different exposures to fumes, gases or dusts at work, and/or to the application and interpretation of statistical methods used especially where the number of cases was small. Sjögren reported that three of the stainless steel welders had died of pulmonary tumours when only 0.68 deaths were expected from calculations using national data. Welders in the Devonport study were unlikely to have been exposed to the hexavalent chromium and nickel in the fume of stainless steel welding. In different occupational situations some compounds of these metals have been shown to be carcinogens. Polednak (1981) studied welders of nickel alloys and others using TIG and SMA on mild steel and aluminium and found that there had been thirteen cases of respiratory death against 9.8 expected. Again the national population statistics were used to calculate the expected number.

Beaumont and Weiss (1981) studied lung cancer deaths in 3247 welders from a variety of industries in one geographical location in America comparing the results with national statistics and then with an internal control population of non-welders. When compared to men of comparable age and race in the general population the 50 deaths due to lung cancer among the total of 529 deaths were 36% more than expected and that excess rose to 74% when the analysis was restricted to the period 20 years and more from the date of first employment as a welder. However, the association of excess lung cancer with the length of exposure was an artefact and the remaining correlation with latency could well be an age effect. Furthermore, welders have been found in this Dockyard investigation and by Dunn et al, (1960), Hunnicutt et al (1964)., and Sterling and Weikham (1976), to smoke more than other occupational groups and this would be expected to contribute to an excess of lung cancer death. They may also have been exposed to asbestos as were those studied by Beaumont and Weiss who conclude that while welders have a relatively high lung cancer risk it is not clear that welding fume is the causative agent.

The three cases of pleural mesothelioma emphasise the importance of assessing other harmful materials in the welders working environment. Sjögren (1980) investigated this and it is remarked upon in some other studies where the subjects may well have been exposed to significant contaminants (Menck and Henderson, 1976., Milham, 1976., Beaumont and Weiss, 1980 and 1981).

At Devonport there was only one death from bronchitis amongst the welders and none from pneumonia. Deaths in Occupational Unit 036 (gas, electric welders, cutters and braziers) recorded in the Registrar General's Occupational Mortality Supplement 1970-72 show an apparent excess of deaths from pneumonia. This is quoted often to support the view that welding has caused considerable ill-health. The data from which the statistics were derived have been examined to demonstrate weaknesses in the methods and to emphasise that great caution must be exercised in using these statistics to reinforce such opinions.

An apparently excessive risk of men in Occupational Unit 036 dying from pneumonia was suggested in the Supplement published in 1958 as deaths assigned to pneumonia numbered 70 against 31 expected, a standardised mortality ratio of 226 whereas deaths assigned to bronchitis yielded SMR of 109 giving the unusually high ratio SMR pneumonia/SMR bronchitis of 2.07. In subsequent Decennial Supplements this ratio has been reducing but remained significantly high (1.60 for deaths 1959-1963, 1.44 for deaths 1970-72). In the 1970-72 Supplement it is suggested, with reservations, that some of the excess may be due to exposure to fumes from welding processes. The data are appraised in the Appendix to this paper and it is concluded that this data may be useful to demonstrate the need for study but not to argue that there is an occupational hazard.

In the Dockyard study the high incidence of cardiovascular diseases was in line with that found in the control groups and the absence of clustering of gastro-intestinal malignancies to one part of that system weighs against an occupational cause. Two papers have remarked upon small numbers of welders dying of relatively rare cerebral tumours. (Ott et al, 1976., Polednak, 1981). There is no evidence of this at Devonport.

There were no large discrepancies between observed and expected deaths in any age group compared with the deaths in the whole group.

5. CONCLUSIONS

This proportional mortality study has revealed no evidence to support the hypothesis that exposure to welding fumes and gases in a shipyard is associated with increased mortality attributable to respiratory diseases or gastrointestinal or cerebral malignancies. There is evidence that occupational exposure to asbestos must be considered in studies of welders' deaths.

References

BEAUMONT, J.J., and WEISS, N.S. (1980)
Mortality of welders, shipfitters and other metal trades workers in Boilermakers. Local No. 104, AFL-CIO
Am. J. Epidemiol, 11,775.

BEAUMONT, J.J. and WEISS, N.S. (1981).
Lung cancer among welders.
J. Occup. Med. 23,12,839.

BLOT, W.J., HARRINGTON, J.M., and TOLEDO, A. (1978).
Lung cancer after employment in shipyards during World War II.
N. Eng. J. Med. 299,620.

BLOT, W.J., MORRIS, L.E., and STROUBE, R. (1980).
Lung and laryngeal cancers in relation to shipyard employment in coastal Virginia.
J. Natl. Cancer. Inst. 65, 571.

BRESLOW, L., HOAGLIN, L., RASMUSSEN, G. (1954)
Occupation and smoking as factors in lung cancer.
Am. J. Public Health 44,171.

CHALLEN, P.J.R. (1974).
Some news on welding and welders.
J. Soc. Occup. Med. 24,38.

DECOUFLE, P., STANISLAWCZYK, K., and HOUTEN, L. (1978).
Retrospective survey of cancer in relation to occupation.
US Dept HEW, National Institute for Occupational Safety and Health.
Publ. No (NIOSH) 77-178.

DUNN, J.E., LINDEN, G., and BRESLOW, L. (1960).
Lung cancer mortality experience of men in certain occupations in California.
Am. J. Public Health 50,1475.

DUNN, J.E. and WEIR, J.M. (1968).
A prospective study of mortality of several occupational groups.
Arch. Environ. Health 17,71.

ENTERLINE, P.E. (1965).
Mortality among asbestos produce workers in the United States.
Ann. N.Y. Acad. Sci. 132,156.

FOX, A.J., and COLLIER, P.F. (1976).
Low mortality rates in industrial cohort studies due to selection for work and survival in the industry.
Brit. J. Prev. Soc. Med. 30,225.

GOLDSMITH, J.R. (1975).
What do we expect from an occupational cohort.
J. Occup. Med. 17.2.126.

HEDSTRÖM, L. (1979).
A cohort study of track welders at Swedish State Railways concerning tumours and mortality.
Arbetarskyddverket, Stockholm, 41-52. Cited by Sjögren, 1980.

HOLDEN, H.J., INGLE, J., MOLYNEUX, M.K.B. and GISBORNE, J.T. (1978).
Occupational hygiene study of Dockyard welding processes: A work situation survey report.
Institute of Naval Medicine Report No. 45/78.

HUNNICUTT, T.N., CRACOVANER, D.J., and MYLES, J.T. (1964).
Spirometric measurement in welders.
Arch. Environ. Health. 8,661.

McMICHAEL, A.J., HAYNES, S.G. and TYROLER, H.A. (1975).
Observations on the evaluation of occupational mortality data.
J. Occup. Med. 17,2,128.

McMILLAN, G.H.G., and MOLYNEUX, M.K., (1981).
Health of Welders in Naval Dockyards - Work situation and sickness absence patterns.
J. Occup. Med. 31,43.

MANTEL, N., and HAENSZEL, W. (1959).
Statistical aspects of the analyses of data from retrospective studies of disease.
J. Nat. Cancer. Institute. 22,719.

MENCK, H.R., and HENDERSON, B.E. (1976).
Occupational differences in rates of lung cancer.
J. Occup. Med. 18,12,797.

MILHAM, S. (1976).
Cancer mortality patterns associated with exposure to metals.
Ann. NY. Acad, Sci. 271, 243.

OTT, M.G., HOLDER, B.B., and LANGER, R.P. (1976).
Determinants of mortality in an industrial population.
J. Occup. Med. 18,3,171.

PETERSEN, G.R., and MILHAM, S. (1980).
Occupational mortality in the State of California 1969-1971.
US Dept. HEW Publ. No. (NIOSH) 80-104.

POLEDNAK, A.P. (1981).
Mortality among welders including a group exposed to nickel oxides.
Arch. Environ. Hlth. 36,5,235.

REDMOND, C.K., and BRESLIN, P.P. (1975).
Comparison of methods for assessing occupational hazards.
J. Occup. Med. 17,5,313.

REDMOND, C.K., WIEAND, H.S., and ROCKETTE, H.E. (1979).
Long term mortality experience of steelworkers.
Update for NIOSH, Contract No. HSM-99-71-32. Cited by Beaumont and Weiss, 1981.

REGISTRAR GENERAL (1978).
Decennial Supplement, England and Wales, Occupational Mortality 1970-72
London HMSO.

SJÖGREN, B (1980)
A retrospective cohort study of mortality among stainless steel welders.
Scand. J. Work. Environ. Hlth. 6,197.

STERLING, T.D., and WEIKHAM, J.J. (1976).
Smoking characteristics by type of employment.
J. Occup. Med. 18,743.

WILHELMSENN, L., OXHO, H., BAKE, B., RINDBY, A., and SELIN, E. (1977).
Investigation on effects of electric arc welding in a Swedish shipyard.
Bull. inst. marit. trop. med. Gdynia. 28,1 and 45.

WORLD HEALTH ORGANISATION (1977).
Manual of the International Statistical Classification of Diseases,
Injuries and Causes of Death, Ninth Revision.

TABLE 1. Summary analysis of main causes of deaths in welders and Control groups

Cause of death	Welders				Control 1				Control 2			
	Number of deaths		PMR	Chi^2 (2)	Number of deaths		PMR	Chi^2	Number of deaths		PMR	Chi^2
	Observed	Expected (1)			Observed	Expected			Observed	Expected		
All respiratory diseases	10	11.2	89	0.07	82	87.5	94	0.98	53	46.2	115	1.64
Bronchitis/Asthma	1	2.3	43	0.35	16	20.1	80	1.72	17	11.6	147	3.38
Respiratory infections	0	2.2	0	1.61	24	19.1	126	3.16	6	8.8	68	0.89
Bronchopneumonia	0	1.3	0	0.54	17	12.9	132	3.06	3	5.8	52	1.38
Lobar pneumonia	0	0.4	0	0.01	2	0.9	211	0.62	0	0.6	0	0.03
Pulmonary tuberculosis	0	0.1	0	3.71	1	1.3	76	0.08	1	0.6	159	0.04
Aspiration pneumonia	0	0.4	0	0.01	4	3.9	104	0.10	2	1.7	118	0.03
Respiratory malignancy	8	6.4	124	0.24	42	47.9	88	1.85	30	25.6	117	1.01
Nasopharyngeal Ca	0	0.3	0	0.11	2	2.3	85	0.03	2	1.3	150	0.03
Ca bronchus	5	4.8	104	0.02	29	35.2	82	2.60	25	19.0	131	2.59
Ca lung + pulmonary fibrosis	0	0.2	0	0	1	1.8	56	0.13	2	1.0	192	0.31
Mesothelioma	3	1.2	259	1.89	10	8.6	116	0.24	1	4.2	24	2.60
Pulmonary fibrosis (asbestos)	1	0.3	333	0.19	0	0.4	0	0.02	0	0.3	0	0.28
All asbestos disease	4	1.6	248	2.73	11	10.9	101	0.04	3	5.5	54	1.11
Gastrointestinal disease	11	6.2	176	3.93	40	41.4	97	0.05	20	23.4	86	0.61
Gastrointestinal Ca	9	5.1	175	2.90	34	34.6	98	0.00	16	19.2	83	0.65
Ca oesophagus	1	0.3	395	0.27	3	3.5	85	0.00	1	1.2	81	0.02
Ca stomach	4	1.6	246	2.58	12	13.8	87	0.31	7	7.6	92	0.00
Ca pancreas	1	0.6	170	0.02	4	3.5	116	0.00	1	2.0	51	0.16
Ca liver	0	0.1	0	3.71	1	0.6	165	0.05	0	0.3	0	0.12
Ca colon	1	0.6	164	0.02	5	4.3	117	0.03	1	2.1	47	0.26
Ca rectum	2	2.0	100	0.16	9	9.0	100	0.06	6	6.0	100	0.06
Cardiovascular disease	25	27.8	90	0.50	234	227.0	103	0.89	115	118.3	97	0.24
Myocardial infarction	18	17.0	106	0.02	146	135.2	108	3.17	59	70.8	83	4.09
Cerebrovascular accident	4	5.0	79	0.07	42	43.8	96	0.11	26	23.2	112	0.4
CNS diseases	2	2.0	100	0.16	10	10.0	100	0.07	5	5.0	100	0.08
Brain tumours	0	0.8	0	0.15	4	4.1	99	0.12	3	2.1	141	0.10
Total	52	52	100	-	395	395	100	-	209	209	100	-

Notes

(1) Age adjusted (5 year band) expected numbers determined from frequency of specific causes of deaths among three groups with adaptation of Mantel-Haenszel procedure.

(2) Mantel-Haenszel summary chi-square (1d.f) for difference between observed and expected deaths.

(3) Causes of death not remarked upon in welders' certificates but present on those of controls are not shown.

Appendix

An appraisal of the use of data in the Registrar General's Decennial Supplement on Occupational Mortality

An apparently excessive risk of men in Occupational Unit 036 (gas, electric welders, cutters, braziers) dying from pneumonia was suggested in the Supplement published in 1958 as deaths assigned to pneumonia numbered 70 against 31 expected, a standardised mortality ratio of 226 whereas deaths assigned to bronchitis yielded SMR of 109 giving the unusually high ratio SMR pneumonia: SMR bronchitis of 2.07. In subsequent Supplements this ratio has been reducing but remains significantly high (1.60 for deaths 1959-63, 1.44 for deaths 1970-72).

In his commentary on the 1970-72 data Dr John Fox suggests that some of the excess may be due to exposure to fumes including those of zinc, cadmium and vanadium. It is recognised that over-exposure to freshly formed metallic oxides may produce the influenza-like condition metal fume fever. This is usually self limiting in 24 hours or so but occasionally symptoms progress or reappear and death may ensue from pneumonitis. One would expect these deaths to be recorded as "accidental poisoning by heavy metals and their fumes" but as Dr Fox remarks it is possible that the certifying doctor may not associate the delayed deaths with the initial attack and may consequently record the deaths as due to pneumonia.

The Certificate of Cause of Death for all men aged 15-64 in Occupational Unit 036 who were included in the mortality statistics for pneumonia, bronchitis, emphysema and asthma in the Occupational Mortality Decennial Supplement 1970-72 were obtained from the Office of Population Censuses and Surveys. The information on these certificates was examined to determine the occupations of the men, the certified cause(s) of death and an estimate of the amount of inquiry which preceded recording these causes.

If the Registrar General's published data and comments were entirely reliable they would raise grave suspicions of exposure to welding pollutants causing an excess of deaths, particularly from pneumonia, in welders. However, while quite firm conclusions can be drawn by relating high standardised mortality ratios for relatively rare diseases and occupational hazards, eg nasal cancers and furniture manufacture, this approach is less likely to identify occupational factors associated with more common diseases because these are likely influenced as much if not more by the conditions and way of life of the workers than by their occupational exposure to noxious agents.

In the case of Occupational Unit 036 the high overall SMR of 122 in 1970-72 was only partly explained by social class standardisation after which the observed deaths were still 18% more than expected, much of the excess being due to respiratory deaths. There may be important within class variations in significant influencing factors especially in smoking habits. Data derived from the General Household Survey shows welders' proportional current smoking ratio to rank 12 in 62 Occupational Units. In studies of Dockyard welders reported earlier, welders were found to smoke more than other craftsmen. As tobacco smoking is known to be related to diseases especially of the respiratory tract this relative excess smoking in welders could be expected to contribute to if not wholly explain the 18% excess death rate.

The fact remains that the ratio of SMR pneumonia to SMR bronchitis has been significantly high for some thirty years. This cannot be explained directly by tobacco smoking and may indicate an occupational influence. However, welding has increased manyfold in that period and thus one might expect to see the ratio steadily increasing as more people are exposed to welding pollutants. The ratio has actually decreased. There is no way of knowing if this is due to improved diagnosis and treatment, improved working conditions or the absence of any relationship between welding and pneumonia but it must cast further doubts on such a relationship.

There were 149 deceased in the Occupational Unit, 137 welders and 12 burners/cutters (Table A). This latter group has been excluded from much of the analysis as the potential respiratory health hazards they faced at work were likely to be different from those produced by welding processes.

Table A. Occupations of men in the study group

Burners and steel cutters	12
All welders	137
Electric arc welders	29
Oxyacetylene welders	5
Spot welders	3
Blacksmith welders	2
Welders, type unspecified	98
Total number of men	149

Different welding processes produce differing fumes and gases and it would have been useful to examine the data for men in different processes separately but in 71.5% of welders the process was not defined in the occupation recorded on the certificate. When a process was specified it was most commonly electric arc welding. The industry in which the man was employed was not specified in 57 cases (41.6%) and in most of the remainder it was very loosely defined thus preventing any meaningful analysis (table B).

Table B. Industries in which welders were employed

Engineering unspecified	27
Light engineering	16
Vehicle manufacture	11
Shipyard	9
Heavy engineering	8
Steelworks	6
Construction	3
Unspecified	57

Pneumonia was the certified cause of death used for classification by the Registrar General in 60 welders and 6 burners/cutters, bronchitis and/or emphysema in 65 welders and 6 burners/cutters while asthma killed 8 welders (table C). The ratio of pneumonia deaths : bronchitis deaths are slightly (but not significantly) greater in burners/cutters than in welders.

Table C. Certificated causes of death in welders and in burners/steel cutters as classified by Registrar General, 1978

ICD Code	Disease	Welders	Burners/cutters
480	Viral pneumonia	2	0
481	Pneumococcal pneumonia	20	1
485	Bronchopneumonia	33	5
486	Unspecified pneumonia	5	0
480-86	All pneumonias	60	6
490	Bronchitis	1	0
491	Chronic bronchitis	64	6
492	Emphysema	4	0
493	Asthma	8	0
490-93	Bronchitis, emphysema and asthma	77	6

It is considered reasonable that if one was to accept the hypothesis that pneumonia was related to an occupational hazard faced by the welder (and should actually have been reported as death from pneumonitis or the effects of the pollutant) that this pneumonia would form the excess but this is not the case (table D) there being 2 cases of viral pneumonia, 20 of pneumococcal (lobar) pneumonia, 33 of broncho-pneumonia and 5 in which the type was not specified.

The accuracy of the diagnosis is likely to improve when there has been a post-mortem examination. This was done in 29 cases, 18 being at the order of the Coroner who in no case recorded a verdict of accidental or industrially related death (table D). In 16 of the cases which were not investigated post-mortem other diseases which commonly precede or predispose to pneumonia were shown on the certificate (table E) but not in a position on the certificate which allowed that disease to be classified as the principal cause of death by the rules which apply. It is impossible to determine in which cases the certificates were not filled out correctly and in how many cases a disease shown in Part II of the certificate should actually have been the last mentioned in Part I. In 15 cases there was no indication of any other disease. As the same standard of certificate completion and the same rules of classification apply to Occupational Group 036 and the base population used in the calculation of SMRs the same potential for error exists and it is thought that this is probably quite significant.

Table D. Number of cases of pneumonia with and without post mortem examination

Disease	Coroner's post-mortem	Other post-mortem	No post-mortem	Total
Viral pneumonia	2	0	0	2
Pneumococcal pneumonia	11	4	5	20
Bronchopneumonia	4	5	24	33
Unspecified pneumonia	1	2	2	5
All pneumonias	18	11	31	60

Table E. Co-existing diseases in welders who died of pneumonia not investigated by post-morten examination

Type of pneumonia	Other diseases in Part I of Certificate	Diseases in Part II of Certificate
Pneumococcal	Cor pulmonale (1), Renal failure (1), Septicaemia (1)	Chronic bronchitis (2)
Bronchopneumonia	Cardiac failure (2)	Myocardial infarction (3), Chronic bronchitis (2), Cerebrovascular accident (4), Presenile dementia (2), Congestive cardiac failure (1), Motor neurone disease (1), Pulmonary embolus (1), Carcinoma of bladder (1).
Unspecified	Ischaemic heart disease (1)	Chronic bronchitis (2)

It is concluded that the Registrar General's stated reservations on the use of SMRs to form causal relationships between common diseases and occupational hazards are fully justified by the observed potential for mis-classification of cause of death. It is further concluded that even if the increased ratio of SMR Pneumonia to Bronchitis is accepted as worthy of raising suspicions its apparent reduction over the years and the apparent absence of an excess of one type of pneumonia reduces the likelihood of that excess being attributable to an occupational hazard. It is thought that the relative excess of tobacco smoking must play a significant part in the causation of the excess of respiratory deaths.

It cannot be concluded that the Registrar General's comments are erroneous; that would require a controlled study at national level over several years which is beyond the resources available to the Medical Research Unit. However, until such a study can be completed the comments in the Occupational Mortality Decennial Supplement should be used only to demonstrate the need for further study rather than to argue in favour of the belief that there is an occupational hazard.

SECTION G

THE RISK OF ASBESTOS RELATED DISEASE OCCURRING IN WELDERS

Summary

Welders employed in HM Dockyards before the late 1960's are likely to have been exposed to asbestos dust at work. Several studies have been made to assess the risk of them developing asbestos related pulmonary parenchymal fibrosis, pleural fibrosis and mesothelioma. The potential exposure and possible effects of this are described.

THE RISK OF ASBESTOS RELATED DISEASES OCCURRING IN WELDERS

1. INTRODUCTION

Since 1966 the incidence of asbestos related diseases has been studied in Her Majesty's Dockyards. The baseline surveys were started at Devonport (Sheers and Templeton, 1968) and extended to Portsmouth, Rosyth and Chatham (Harries et al, 1972 and 1976). I took over the direction of much of the follow-up research between 1975 and 1978 and assisted in other studies conducted during that period by Medical Research Council Pneumoconiosis Research Unit staff and by Dr Geoffrey Sheers, Beaumont House Chest Clinic, Plymouth. Although this research was not designed to study asbestos disease in welders specifically they formed part of the groups studied. The incidence of these diseases among welders and the risks of them developing the diseases have been estimated, mainly at Devonport.

2. WELDERS' SOURCES OF EXPOSURE TO ASBESTOS AT WORK

With the introduction of steam propelled warships came the need to contain heat in boilers and pipework. Various insulating materials were tried but none was as efficient as asbestos and first crocidolite and later amosite were used extensively in shipbuilding, repair and refitting until the mid to late 1960's. Few, if any, precautions were taken to prevent inhalation of asbestos fibres and men often worked in very contaminated atmospheres. Delagging during repair and refitting produces higher counts than in lagging. Machinery spaces and boiler-rooms in warships are more cramped than their commercial counterparts and this added to difficulties of good "housekeeping". In the early 1970's the first dust measurements were taken. Men wore full protection which was just as well as delagging in boiler-rooms produced mean values of 171 fibres/ml (figure E1), engine rooms 88 fibres/ml (figure E2) while sweeping and bagging the very friable debris 353 fibres/ml. Many welders were exposed to similarly high levels when working in the affected compartments or to rather lower levels elsewhere in the ship as dust was circulated by ventilation or tramped through by workmen with contaminated clothes and footwear. Bell (1976) describes welders working in asbestos contaminated atmospheres in Australian shipyards. Peters et al (1973) and Beaumont and Weiss (1981) mention welders' exposure to asbestos.

Asbestos was used as fireproofing especially on the underside of the flight decks of aircraft carriers, that is on the deck head of hangars and adjacent compartments. Dry crocidolite was emptied into mixing bins, producing much dust and mixed into a paste with water. Welders welded strips of steel to the deckhead then laggers sprayed this limpet asbestos paste over the area. The layer of paste was held in place by steel netting secured by the welded strips then sealed with cement. No respiratory protection was used. Welders described long tendrils of fibre hanging from their nostrils as they worked. The wet paste dried out on their overalls giving them further doses.

Frequently this lagging had to be broken into to allow other fixtures to be welded in place. Rather than waiting for a lagger to do this the welders often did it themselves. Delagging limpet asbestos has produced fibre counts averaging 334 fibres/ml (figure E3).

Further, but probably much less significant, exposure was from the use of asbestos cloth sheeting to protect the welder from sparks and hot slag. They used to wrap themselves in this in confined spaces or made aprons from it. Dust emission was highest when it was being "tailored" by tearing it, and when it had been in use for some time and became brittle. Exposure from asbestos wound electrodes may have been comparatively insignificant but Bell (1976) has found that similar crocidolite wound rods produced 16-18 fibres/cc when used in a well ventilated workshop.

During the research studies in the Yards in the mid and late 1960's many hundreds of men were interviewed to determine the potential exposure of different occupational groups and on this basis each occupation was allotted to one of four exposure groups (Harries et al, 1976). These studies included examination of 10% random samples at Devonport (Sheers and Templeton, 1968) and Portsmouth (Harries et al, 1972). When I followed up these samples in 1976 and 1977 respectively I re-interviewed the survivors and refined the occupational history groupings and made slight adjustments to the composition of the exposure groups. In both sets of investigations welders were in the second highest of the four risk groups, ie exposure group 2 (McMillan et al, 1978 and 1979).

3. THE EFFECTS OF ASBESTOS EXPOSURE ON THE HEALTH OF WELDERS

Inhalation of asbestos may cause discrete plaques of pleural fibrosis which may become calcified, diffuse pleural fibrosis which may be associated with pleural effusions, parenchymal fibrosis, pleural and perhaps peritoneal mesothelioma. It is thought to increase the risk of bronchial carcinoma especially among those who smoke. The prevalence rate per cent of these lesions in exposure group 2 of the random samples examined at Devonport was 13.4% and at Portsmouth 13.3% (McMillan et al, 1978 and 1979).

Parenchymal fibrosis

Fortunately the prevalence of parenchymal fibrosis was low in exposure group 2 in both Yards at 1.1% and 0.5% respectively. In the clinical examination phase of the main health of welders study when 306 welders were examined, 13 were found to have small irregular opacities ILO/UC 1971 category 1/1 or more in their full size chest radiograph. Seven had dyspnoea but none had persistent rales nor restrictive pattern lung function test results with reduced gas transfer factor, the criteria which it would appear have to be satisfied if the man is to be awarded a DHSS disability pension. Only three men of those who have been employed as welders at Devonport are known to have such a pension for asbestos parenchymal fibrosis.

Mesothelioma

Only one case of mesothelioma was found in the sample surveys at Devonport and none at Portsmouth. This case was in exposure group 2 but was not a welder. Sample surveys are a poor indicator of the incidence of such a rare tumour. The first case at Plymouth (the city in which Devonport lies) was diagnosed in 1964 and since then Dr G Sheers has maintained a register of all cases occurring in Plymouth where the completeness of cancer registration has been better than average and where there has been a high awareness level of the possibility of the diagnosis. In collaboration with that work, staff at the Medical Research Unit checked all cancer registrations and death certifications between 1960 and 1966 and since then the Unit has maintained a check on death certification. One death in thirteen may not be detected because of men moving from the area (McMillan et al, 1978).

A total of 108 cases of mesothelioma was recorded to 1978 (Sheers and Coles, 1980) with autopsy in 101 and biopsy specimens in the remaining 7. Ninety six were associated with work in the Dockyard; three were welders. A further four deaths of welders from mesothelioma have occurred between 1978 and 1981. Therefore seven welders are known to have died of the tumour in Plymouth. Regrettably, similar data are not available for the other Yards.

Non-malignant pleural fibrosis

The vast majority of asbestos related lesions found in the sample studies were of the non-malignant pleural fibrosis type. In Devonport, exposure group 2 24 men had simple pleural plaques, 11 had calcified pleural plaques, and five had diffuse pleural fibrosis. At Portsmouth the numbers were 19, 10 and 4 respectively. When I examined the welders at Portsmouth, Devonport and Chatham the incidence of pleural lesions was higher at 86 cases in the

306 men, 28.1%. The difference may be due to the sample surveys being based on miniature radiographs and the main welders study on full size films (Sheers et al, 1978).

Pleural plaques have been seen as objective indicators of previous exposure to asbestos (Becklake, 1976., Hillerdal, 1978) and, while they are harmless in themselves (Hillerdal, 1980) it has been recommended that those with the abnormality should be followed up closely (Kendall and Caplin, 1967., Sargent et al, 1977., Moigneteau et al, 1977., Anderson and Selikoff, 1978). Hillerdal (1980) contends that from a medical point of view, only limited gains are to be expected by such follow-up. He has reported that most of the patients with pleural plaques he subjected to extensive lung function tests had early fibrosis with stiff lungs and reduced volumes although they had no symptoms and concluded that there is often subclinical parenchymal fibrosis in persons with typical pleural plaques. In another dockyard population it has been shown that the incidence of bronchial carcinoma was twice as high in those with pleural plaques as in those without but with the same exposure (Fletcher, 1972., Edge, 1976). There is no evidence that men with pleural plaques have an excess incidence of mesothelioma.

Diffuse pleural thickening involving the visceral pleura may occur with or without pleural plaques and, when extensive, can cause restrictive lung function changes (Lumley, 1977). Sheers (personal communication) has described 52 cases where there has been an acute pleural reaction consisting of either an effusion or a striking increase in the extent of the pleural reaction within a short period of time. In 35 this has been the first indication of any asbestos related disorder while the remainder occurred in previously recognised cases of diffuse pleural thickening. While it may be difficult initially to differentiate between this acute reaction and mesothelioma there is no firm evidence that either diffuse thickening or this reaction carry an excess risk of mesothelioma.

4. THE DEVELOPMENT OF RADIOLOGICAL AND CLINICAL EVIDENCE OF PARENCHYMAL FIBROSIS IN MEN WITH NON-MALIGNANT ASBESTOS RELATED PLEURAL LESIONS

Rossiter and I decided that the relatively high prevalence of pleural lesions merited further study to determine if there was any prognostic significance with respect to development of parenchymal fibrosis. We were fortunate in that records of a group of men suitable to our purpose were available.

In 1970 the full size PA chest radiographs and clinical records of all men who had been referred to the Medical Research Unit in Devonport Dockyard or to Plymouth General Hospital Chest Clinic with suspected asbestos related pleural lesions detected mainly during mass miniature radiography in the Dockyard had been reveiwed by Surgeon Commander Harries and Dr Sheers.

Follow-up was initiated for those in whom the diagnosis had been confirmed. To determine the attack rates of parenchymal fibrosis, mesothelioma and bronchial carcinoma over a ten year period we recalled the survivors of those who had been exposed at work in the Dockyard and examined in 1966 (when protective measures were introduced) for radiographic and clinical examination in 1976. Radiographs taken and records of examination at routine follow-up within 12 months of death were obtained for men fulfilling these criteria but had died by 1976. Asbestos exposure was assessed from a detailed occupational history (McMillan et al, 1978) as actual exposure measurements were not available.

The full size PA chest radiographs taken in 1966 and 1976 were read independently, in random order and without knowledge of date to an extended version of the ILO/UC 1971 Classification by three experienced readers (Drs G Sheers, J.C. Gilson and K.P.S. Lumley). The extension of the 1971 Classification required pleural changes to be differentiated into pleural plaques or diffuse pleural thickening.

In an attempt to reduce inter-reader variation a selection of full size chest radiographs from other surveys of the Dockyard population which were considered to exhibit the complete range of asbestos related lesions, other pathologies or no abnormalities, were presented to the three readers in committee and they were required to agree on the ILO/UC Classifications of each radiograph. These radiographs could not be distinguished from the survey films and were mixed randomly in the ratio 1:7 in each batch of films during the independent reading. Each reader's clerk could identify the "trigger films" from the reading sheet and, after the reader had dictated his classification he was presented with the agreed classification for comparison in the hope that variation in reading standard would be minimised.

For every aspect of radiographic abnormality the agreed reading of at least two of the three readers was used in the tabulations. Small irregular opacities were considered to be present when this reading was category 1/1 or more. The agreed reading of the 1966 radiographs showed asbestos related pleural lesions without co-existing small opacities, mesothelioma nor carcinoma in 201 cases. These men were the subjects of the study. The classification of the 1966 radiograph was used to allocate each of these men to one of four categories of pleural abnormality; uncalcified pleural plaques, calcified pleural plaques, diffuse pleural thickening and diffuse thickening with plaques. The difference between that film and the follow-up film thus allowed assessment of the development of new lesions in relation to the pre-existing pleural lesions.

The full results are given in McMillan and Rossiter 1982 and are summarised in table G1. One hundred and sixty nine of the 201 men were alive in 1976 and 155 attended for examination. Twenty of the 32 men who had died had had a follow-up radiograph and examination by at least one physicion involved in the Naval Dockyards Asbestos Survey. Data on all these men were combined. Nine (9.1%) of the 99 men in exposure group 2 attained a classification of small opacities 1/1 or more by 1976 or their death. This radiological data suggests that some 9% of welders in Devonport Dockyard who have had sufficient exposure to develop pleural changes (but not small opacities of category 1/1) can be expected subsequently to develop small opacities 1/1 or more within 10 years of identification of the pleural lesion. The type of pleural lesion, time since first exposure, occupation, age and smoking habit do not appear to be the factors which determine which of the men will be affected.

When strict clinical criteria were added to the radiological classification we considered that 3.0% had clinical parenchymal fibrosis. This was in sharp contrast to that in men in the random sample survey who had neither pleural nor parenchymal lesions in 1966 where the attack rate was 0.5%. (McMillan et al, 1978).

This strengthens but does not confirm our opinion that men with pleural lesions are more likely to develop parenchymal fibrosis than their similarly employed colleagues with no pleural lesions. Our caution is based on important differences between the two groups of men. When the groups are divided by occupation, an indicator of severity of exposure, there are relatively more men from the 155 men with pleural lesions in the heaviest exposure group 1 and fewer in the lightest exposure group 3. Overall there are relatively more non-smokers in the larger sample and their mean duration of exposure was about four years shorter. However, the relative number of men and smokers are similar in exposure group 2, but the attack rates are very dissimilar (though based on small numbers). Furthermore, 100 mm radiographs were used to screen the larger sample and determine which men required further examination by full size radiograph. Although a very low threshold of suspicion was maintained when examining the smaller films it is likely that some cases of small opacities were missed though unlikely that these included any of classification 1/1 or more.

Thus it is concluded that asbestos related pleural lesions may not be merely "markers" of previous exposure to asbestos but may identify those at greatest risk of developing parenchymal fibrosis. The small number of cases of mesothelioma and the sole case of bronchial carcinoma do not allow conclusions to be drawn with respect to their relationship with benign pleural lesions.

5. CONCLUSIONS

Many welders have had heavy exposure to asbestos dust at work in the Dockyards and as a result between 0.5 and 1.1% have developed parenchymal fibrosis, and approximately 13.0% have developed non-malignant pleural lesions. Of the latter group of men some 9% are likely to develop radiological evidence of parenchymal fibrosis and 3.0% to have clinically detectable parenchymal fibrosis within 10 years of diagnosis of the pleural lesions. Although at least 7 welders at Devonport have died from pleural mesothelioma it is not possible to estimate incidence at present or for the future.

REFERENCES

ANDERSON, H.A., and SELIKOFF, I.J. (1978).
Pleural reactions to environmental agents.
Fed. Proc. 37,2496-2500.

BEAUMONT, J.J., and WEISS, N.S. (1981).
Lung cancer among welders
J. Occup. Med. 23,12, 839-844.

BECKLAKE, M.R., (1976)
State of the Art. Asbestos-related diseases of the lung and other organs: their epidemiology and implications for clinical practice.
Am. Rev. Resp. Dis. 114,187-227.

BELL, A. (1976).
Industrial hygiene and occupational health studies in Australian (New South Wales) Shipyards.
Environ. Res. 11,198-212.

EDGE, J.R. (1976).
Asbestos-related disease in Barrow-in-Furness.
Environ. Res. 11,244-247.

FLETCHER, D.E. (1972).
A mortality study of shipyard workers with pleural plaques.
Br. J. Ind. Med. 29,142-145.

HARRIES, P.G., MacKENZIE, F.A.F., SHEERS, G., KEMP, J.H., OLIVER, T.P. and WRIGHT, D.S. (1972).
Radiological survey of men exposed to asbestos in Naval Dockyards.
Br. Med. J. 29,274.

HARRIES, P.G., ROSSITER, C.E., and COLES, R.M. (1976).
Royal Naval Dockyards Asbestosis Research Project.
Royal Navy Clinical Research Working Party Report 1/76. Alverstoke, Gosport.
Institute of Nav. Med.

HILLERDAL, G. (1978).
Pleural plaques in a health survey material. Frequency, development and exposure to asbestos.
Scand. J. Res. Dis. 59,257-263.

HILLERDAL, G. (1980).
Pleural plaques, Occurrence, exposure to asbestos and clinical importance.
Doctoral thesis, Uppsala University.

KENDALL, B., CAPLIN, M. (1967).
Pleural calcification.
Br. J. Dis. Chest 61,126-30.

LUMLEY, K.P.S. (1977).
Physiological changes in asbestos pleural disease.
In: Walton, W.H. ed. Inhaled Particles IV, Proceedings of International Symposium. Oxford and New York: Pergamon Press, 781-787.

McMILLAN, G.H.G., SHEERS, G., and PETHYBRIDGE, R.J. (1978).
A radiological follow-up study of the effect of asbestos in Dockyard workers at Devonport.
J.R. Nav. Med. Serv. 64,2,88

McMILLAN, G.H.G., SHEERS, G., and PETHYBRIDGE, R.J. (1979).
A radiological follow-up study of the effect of asbestos in Dockyard workers at Portsmouth.
J.R. Nav. Med. Serv. 65,2,63.

McMILLAN, G.H.G., and ROSSITER, C.E. (1982).
The development of radiological and clinical evidence of parenchymal fibrosis in men with non-malignant asbestos related pleural lesions.
Br. J. Ind. Med. 39,54.

MOIGNETEAU, C., TOUZEAU, P.Y., and GUILLEMENT, J.M. (1977).
Calcifications pleurales asbestosiques et pathologie associée (étude des 32 observations).
Pnoumon Coeur; 33,101-107.

PETERS, J.M., MURPHY, R.L.H., FERRIS, B.G., BURGESS, W.A., RANADINE, M.V. and PERDERGRASS, H.P. (1973).
Pulmonary function in shipyard welders.
Arch. Environ Health 26,1,28.

SARGENT, E.N., JACOBSON, G., GORDONSON, J.S. (1977).
Pleural plaques: a signpost of asbestos inhalation.
Semin Roentgenol; 12,287-297.

SHEERS, G., and TEMPLETON, A.R. (1968).
Effects of asbestos in Dockyard workers.
Br. Med. J. 3:574.

SHEERS, G., ROSSITER, C.E., GILSON, J.C. and MACKENZIE, F.A.F. (1978).
UK Naval Dockyards Asbestos Study.
Br. J. Ind. Med. 35,195.

SHEERS, G., and COLES, R.M. (1980).
Mesothelioma risks in a Naval Dockyard.
Arch. Environ. Hlth. 35.5.176.

TABLE G1 Comparisons of attack rates of small opacities category 1/1 or more, clinically confirmed, parenchymal fibrosis, smoking habits and duration of potential exposure in men with pleural lesions in 1966, Group A, (this paper), and with no pleural lesions in 1966, Group B (McMillan et al, 1978).

Exposure group	Occupations	Group	Number of men followed up	Percentage in each smoking category			Mean duration (years) of occupational exposure	Percentage (and No.) with S/O 1/1 or more	Percentage (and No.) with S/O 1/1 or more, signs and LFT changes of parenchymal fibrosis	Percentage (and No.) with clinical and radiographic diagnosis of parenchymal fibrosis
				S	Ex-S	Non-S				
1	Lagger, Asbestos Sprayer, Sailmaker	A	18	61	22	17	20.5	5.5 (1)	5.5 (1)	
	Lagger, Asbestos Storeman, Painter afloat	B	29	41	41	17	18.5			3.4 (1)
2	Electrical fitter, Caulker, Rivetter, Coppersmith, Ship fitter, Boiler-maker, Driller, Welder, Burner, Joiner, Plumber, Shipwright, Mechanical fitter	A	99	47	36	17	22.0	9.1 (9)	3.0 (3)	
		B	607	44	29	27	18.3			0.5 (3)
3	All other occupations in Dockyard	A	38	58	39	3	20.8	15.8 (6)	8.0 (3)	
		B	335	56	29	15	17.6			0.6 (2)
1-3	All occupations	A	155	51	35	14	21.5	10.3 (16)	4.5 (7)	
		B	971	48	29	22	17.8			0.6 (6)

Figure G1. Delagging ship's boiler room could produce asbestos dust concentrations averaging 171 fibres/ml. Effective respiratory protection as worn by the men illustrated was not worn before the late 1960's.

Figure G2. Industrial housekeeping was very inadequate during delagging in engine rooms as illustrated. Fibre counts were of the order of 88 fibres/ml.

Figure G3. Clouds of asbestos dust were produced cutting channels through deckhead insulation. Welders used to do this without respiratory protection.

SECTION H

WELDERS HEALTH EXAMINATIONS

Summary

No medical examination should be conducted within industry until the reasons for it have been defined on a scientific basis and can be explained to the employees. In this section the various types of medical examination which may form part of an occupational health conservation programme are defined and their relevance to those exposed to fumes and gases arising from welding is considered. A health screening programme, designed to detect those who are at special risk, is proposed.

1. INTRODUCTION

In 1976 the Commission on Health and Safety of the International Institute of Welding published a recommendation that all welders should be given the opportunity every five years to have a comprehensive medical examination including assessment of lung function. This was based on the belief that welders were at greater risk of developing occupationally-related disease than many other craftsmen and therefore merited special medical surveillance. This was fiercely, but inconclusively, debated at the Annual Assembly in 1977.

I was invited to prepare a revised and more detailed recommendation of an acceptable minimum standard of health supervision (McMillan, 1980), and this was accepted by the Commission in 1979.

As welding is one of the basic industrial processes employing thousands of men in the United Kingdom alone, the widespread adoption of a regime of comprehensive physical examinations would have far-reaching effects on occupational health services, and would widen the gulf in health care between welders in organizations with and without a health service. Our limited resources could be utilized to the greater benefit of welders and their employers if routine clinical examinations were replaced by health screening, designed to identify those who may be oversusceptible to welding fumes and gases, and who may not be protected in areas where the levels of these pollutants are maintained below the Threshold Limit Values. The proposed scheme is based on this principle and should provide an acceptable minimum standard of supervision.

Management can be much comforted by routine medical examinations and often agrees to provide these in the absence of a prima facie case, if only to improve industrial relations. While doctors in industry should encourage increased awareness of the importance of a safe working environment, we have a responsibility to advise both management and employees, ensuring that the former are not faced with ill-informed demands for special surveillance. We must emphasize the necessity of a definite scientific basis for any examination.

Physical examinations are expensive and time-consuming. The employee is removed from productive work while the doctor is confined to the Medical Centre when it may be more useful to be out and about in the workplace or doing other preventive tasks. When one group of employees is singled out for more careful medical attention they may interpret this as indicating that they are exposed to greater hazards than others and quite properly, will insist that these hazards are explained to them and controlled. No medical examination should be conducted until the reasons for it can be defined and explained to the employees. The examination should seek specific abnormalities.

It may be timely to reflect on the seven basic roles of the medical or health examination in industry in general, and in particular their relative usefulness in monitoring and improving the health of welders.

2. EMPLOYEE EXAMINATIONS

Pre-employment

This is used to assess the health of potential employees in relation to their proposed duties, to ensure that they are fit for work, that the work will not aggravate any existing ill health and that they are not unduly susceptible to recognized hazards. This examination may be conducted as a series of screening procedures and delegated to trained ancillary staff, for example the occupational health nurse.

Exposure to Recognized Potential Hazards

This examination is designed to assess the suitability of the employees for exposure to controlled hazards (such as ionizing radiation, extremes of heat, cold or pressure) bearing in mind the possibility of accidental overexposure. The stress of responsibility could be included in this category. The scope for delegation of this examination to nurses depends largely on the hazard and legal requirements. In many cases the nurse will perform most of the examination, taking the opportunity to discuss preventive aspects of safe systems of work. Legislation may require the doctor to conduct the examination, or he may decide that the hazard is such that he should take the opportunity to discuss it personally with each employee.

Biological Monitoring

Biological monitoring is used to ensure that environmental control of specific hazards is sufficient to prevent ill health. It is an adjunct to environmental monitoring and can only be used when the level of exposure and its biological effects can be correlated, eg lead, benzene and noise.

Return from Sickness Absence

This is often a useful time to examine employees. The extent of the examination will vary from case to case, many being given an automatic clearance and the vast majority of the remainder being interviewed and cleared to return to work by the nurse. The limits of his or her authority must be clearly defined to ensure that the doctor is not 'over-protected'. This examination improves the chances of suitable rehabilitation or relocation being achieved when necessary, and reduces the opportunity for well-meaning line managers to arrange this without medical advice. There should be routine surveillance of sickness absence data, presented meaningfully, for each group and for individual employees.

Safety to Others

The safety of other workers is increased by examining employees for whom the safe performance of their task requires specified standards of health, eg visual acuity and fields in crane drivers. Some of these jobs require the doctor to examine the employee, but often a restricted examination by a nurse is sufficient.

Research

Research is needed to investigate clinical suspicions of the existence of a previously undefined hazard.

General Health Screening

Finally, general health screening is performed to assess the overall health status of employees to determine their continuing fitness for their job, the need for any therapeutic measures (medical or environmental) or perhaps their suitability to join a superannuation scheme. As those whose job entails a defined potential risk to themselves or others are already dealt with, these examinations are not strictly occupational health procedures and should be afforded low priority.

3. EXAMINATION OF WELDERS

Now, which of these examinations can benefit the welder? First, we have to recognize that welding is a generic term encompassing a wide variety of methods of joining metal by the application of heat, each with potential hazards. The realization of this potential often depends on the worksite. Therefore, the doctor and nurse must visit the various workplaces and find out which processes are used in different situations and the potential or actual hazards which exist.

The overall impression gained from the extensive literature on welders' health, and not contradicted by my own work described in earlier sections, is that certain groups of welders may have an excessively high prevalence of chronic obstructive airways disease. The first are those exposed for prolonged periods to levels of fumes and gases in excess of the Threshold Limit Values. Their recognition and protection will not be best achieved by any type of medical examination. Secondly, there is a small minority who will not be protected even when exposure is less than the TLV, and those who have pre- or co-existing chronic obstructive airways disease, especially tobacco smokers.

The acute effects of overexposure to fumes, gases or ultraviolet radiation such as metal fume fever or arc eye, will be neither detected nor prevented by routine physical examination. Welders therefore require health surveillance designed specifically to detect obstructive airways disease. A suggested scheme is illustrated in Fig. G1. It is based on a pre-employment or initial health interview and examination of lung function, ongoing monitoring, an annual formal review of sickness absence and interviews on return from absence attributed to lower respiratory tract disease. Provision is made for special examinations of welders employed in certain processes. There is no place for routine comprehensive physical examination by a doctor.

All potential and current employees who will weld or be otherwise exposed to welding fumes and gases should be interviewed by the nurse using a questionnaire based on the MRC Respiratory Symptoms Questionnaire.

Dynamic lung volumes (FEV_1 and FVC) and eye-to-work distance visual acuity (wearing spectacles if these are worn when welding) should be measured using simple techniques. (Welders with defective vision may have to bring their eyes and thus the breathing zone closer to the plume than if vision is normal or properly corrected). The doctor must prepare guidelines to ensure that the nurse can determine which welders need be referred for his opinion, as he should be involved only when fitness is suspect.

Welders with absence attributed to lower respiratory tract disease should be re-assessed on return to work and periodically all welders and allied workers should be interviewed and have the simple examinations performed to update their occupational and respiratory health history and lung function. The opportunity to emphasize the harmful effects of smoking and the importance of minimizing exposure to fume should not be neglected.

It is impossible to make any all-encompassing recommendation about the periodicity of the nurse's re-assessment of welders who are not involved in specifically hazardous processes such as arc air gouging and have no significant sickness absence. As the objective of the scheme is to detect the oversusceptible, it would be rational to review new entries to the craft after a relatively short period, perhaps three months, then at the end of the first year. Intervals of five years may be appropriate for established welders. When abnormalities are detected at re-assessment, action should be decided on an individual basis and only after the man's welding technique and use of extractors and other pollutant control measures have been investigated to ensure that he is minimizing his exposure.

The results of the examinations and interviews should be recorded in a way which allows easy comparison of serial results and thus detection of changes in individuals, and also permits groups of welders to be studied.

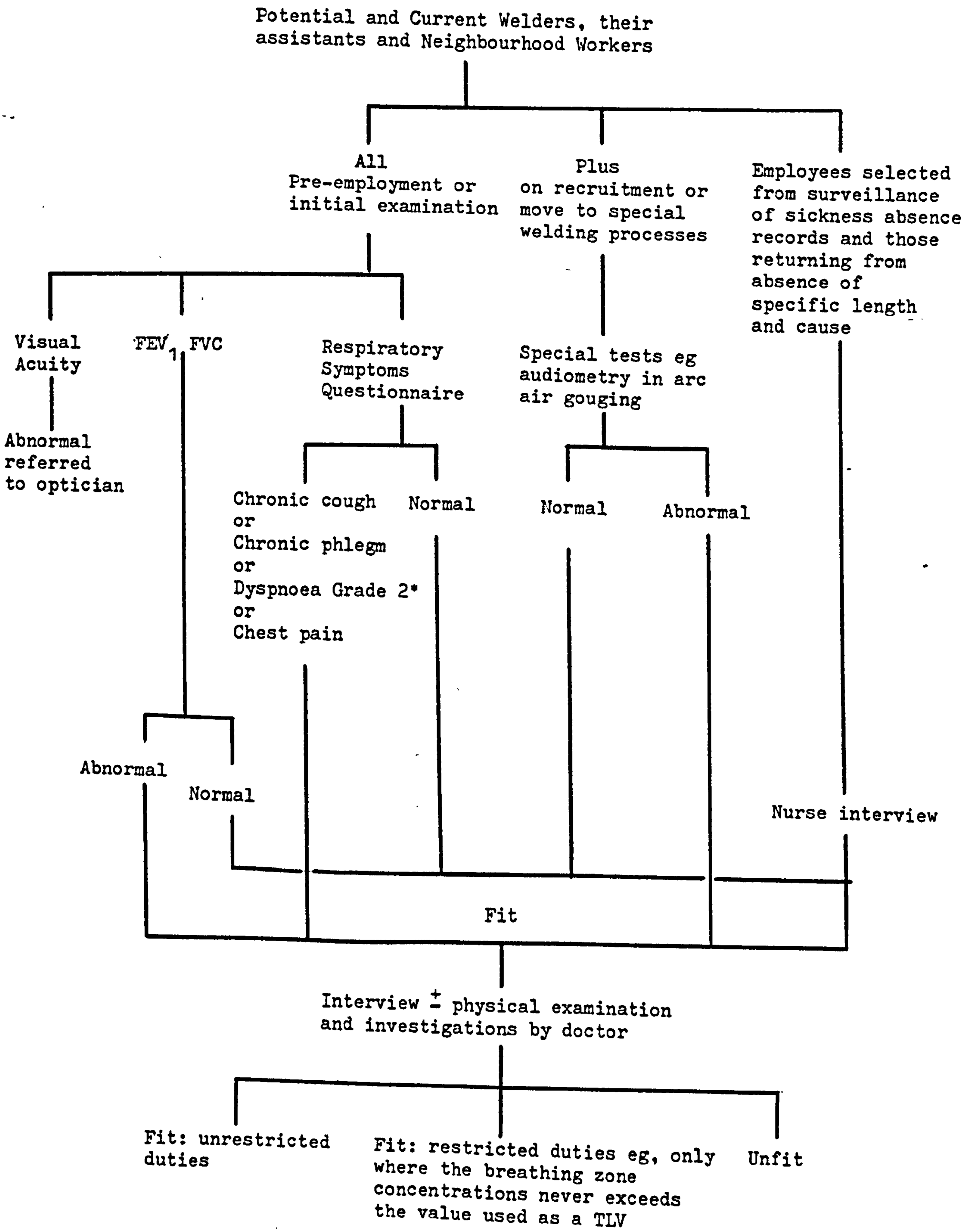
Chest radiography is not included in this minimum standard. While it is recognized that some welders may develop siderosis, the current consensus of opinion is that this is not damaging to health in the short or long term and therefore there is no real advantage in detecting it. Similarly, there is no evidence to suppose that welders are at greater risk of developing other chest diseases which would not be detected by the questionnaire and lung function tests. Routine radiography would be appropriate only when a hazard such as exposure to asbestos may have existed in the past.

This scheme should ensure that any welder who has, or appears to be developing obstructive airways disease is brought to the attention of the doctor for review of fitness to continue in areas where fume levels cannot be maintained below the Threshold Limit Values. It will also assist in ensuring that the examinations are cost-effective and cost-beneficial, and do not create unfounded anxiety among employees nor tedium among the doctors.

Routine clinical examinations of welders are unlikely to be a fruitful source of new knowledge except as part of a controlled study or to provide a base line for a long term cohort study.

REFERENCE

McMILLAN, G.H.G. (1980)
Health of welders, those in similar trades, their assistants and neighbourhood workers.
Welding in the World 18,5/6,115.



*dyspnoea when walking up hills at a normal pace with others of same age

Figure H. Proposed scheme of health surveillance of welders and those who work closely with welders.

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